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A S T U D Y O F
O B S E R V A T I O N A L A T T A I N M E N T
I N P R A C T I C A L W O R K
I N S C H O O L C H E M I S T R Y

By

JAMES E. WARD

A T H E S I S S U B M I T T E D F O R T H E D E G R E E
O F D O C T O R O F P H I L O S O P H Y

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DEDICATION

I wish to dedicate this work to my family, in grateful recognition of their tolerance and understanding over what must have seemed an eternity.

A C K N O W L E D G E M E N T S

I wish to acknowledge my deep gratitude to Professor Richard F. Kempa of the Department of Education at the University of Keele, Staffordshire, England. Throughout the period of the research he has been unstinting in his encouragement and guidance, and I owe much to him.

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A B S T R A C T

The research described in this thesis concerns three separate, but interrelated aspects of observation in chemical education at the secondary school level:

- a) The effect of different modes of task definition and presentation upon students' observational attainment;
- b) The relative effectiveness of different teaching methods, based upon different task presentation modes, upon students' observational competence;
- c) The interpretability and interpretation of observational data of different levels of "quality" and "correctness" by students.

These three aspects were examined in three phases of the study, labelled, respectively, the task definition study, the teaching study and the problem-solving study. The latter of these was conducted as an exploratory investigation only. As a precursor to these, an investigation into observational threshold values was conducted as a means of determining limits of "observability" of different observational stimuli encountered in school chemistry practical work. The purpose of this was to facilitate the development of "standardised" observational tests for use with 'O'-Level/CSE chemistry students.

In the task definition study, observational attainment was determined under three different conditions of task definition representing no cueing, partial cueing and complete cueing to possible observations. Using fourth-form students as subjects, it was found that an approach based on complete cueing produces a significantly higher observational attainment than the other two approaches, but also produces a significantly higher illusory error rate. Errors of omission are similar for the groups exposed to no cueing or partial cueing only, but for the latter appear significantly higher for non-cued observations than for cued observations.

For the teaching study, a two-term laboratory teaching programme was designed in three different formats based on the modes of task definition described above. The programme was used with three different groups of second-form pupils in three consecutive

years. Tests of observational attainment and competence, administered at the end of the two-term leaving phases, showed no significant differences to accrue from the three different treatment formats incorporated in the teaching schemes, although the modes of testing produced differences similar to those found in the task definition study.

Finally, in the problem-solving study, sixth-form students were presented with observational information, concerning qualitative experiments in chemistry, which represented different degrees of completeness. By means of a self-reporting technique, students' behaviour in interpreting this information was examined. The findings from this part of the study are only tentative, but indicate that

- (i) students do not acknowledge the limits of interpretability of observational data;
- (ii) when faced with information about observations made in sequence, students fail to carry forward interpretations from one stage to the next;
- (iii) students are significantly "hindered" in their objectivity in interpretational situations by previously encountered phenomena.

C O N T E N T S

Acknowledgements

Abstract

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I Introduction

Most science educators agree that the laboratory is an integral and necessary aspect of the learning experience in science courses. This is reflected by a number of curriculum development projects in chemistry which are essentially laboratory based. One has only to consider that, since the late fifties, the emergence of the Chemical Education Materials Study Approach (1961), the Chemical Bond Approach (1963), the Nuffield 'O'-Level Sample Scheme (1966) and work by the University of London at the Advanced Level of G.C.E. have all demonstrated the use of a problem-solving approach to practical chemistry, rather than simply using the laboratory to illustrate and verify facts already established in the classroom.

A recent development by Greatorex and Lister (1980), of a Mode 3 'O'-Level Chemistry course is centred around a problem-solving approach used in connection with project work. The students, faced by a particular chemical problem area, are expected to:

- i) plan how to solve that problem;
- ii) execute experiments which have been planned (this stage includes both the manipulation of apparatus and the observation of phenomena resulting from the manipulative stage);
- iii) attempt to solve the problem using data acquired in stage ii; and
- iv) draw suitable conclusions and present the findings.

A number of writers have also assessed and analysed the extent to which practical work features in science courses and the nature of the practical work actually undertaken by students. For instance, a recent study by Shymansky and Penick (1979) sets out to investigate student behaviour in science laboratories, and they came to the conclusion that, of the total time spent in chemistry laboratories at the College level, between 35% and 55% of the time was devoted to experimentation.

Another study, this time made purely on practical chemistry (the Shymansky and Penick study examined other science disciplines) by Ben-Zvi, Hofstein, Samuel and Kempa (1977) showed, on the basis of a factor-analytic study, three main factors to be associated with practical work:

- i) the problem-solving mode;
- ii) the manipulative mode; and
- iii) the observational mode.

This particular study, and the work of Greatorex and Lister confirm and support the assumption set out in the Nuffield 'O'-Level Sample Scheme already referred to, where it was suggested that pupils should be made aware of three important phases of laboratory work; they should

- i) be able to plan how to tackle a problem;
- ii) know how to carry out the required experimental work; and
- iii) be able to discuss what deductions may and may not be made from the results.

Furthermore, in the Nuffield Sample Scheme, the authors state that pupils must be given the opportunity to observe

and explore, so that they develop disciplined, imaginative thinking. The authors also emphasise the need to record observations accurately prior to the interpretative phase.

Therefore, if the purpose of experimental work, apart from the development of experimental skills, is the furtherance of insights into and the understanding of chemical ideas and patterns, then the ultimate emphasis must lie in the drawing of conclusions and the interpretation of data that are the result of careful observation and measurement. This is endorsed by the work of Molitor and George (1976), which emphasised the major part that the observational phase plays in the educative process in chemistry, in that the major activity involved in data collection is observation, that is, the accurate and trained use of the senses.

This is not to say that the manipulative phase is less important, but this particular area of the subject has been the focus of a fair number of investigations which refer either to the provision of skill-training or to the assessment of such skills. Examples of the former type of research can be found in the work of Kempa and Palmer (1974), which investigated different ways of teaching manipulative skills in undergraduate chemistry courses using video tapes; in the work of Matthews (1971), who was concerned with the development of accuracy and precision in volumetric analysis; and in the work of Beasley (1979), who examined the effects of physical and mental practice on psychomotor skills, i.e., 'learning by doing' on the one hand and learning by introspective, 'mental' practice on the other.

Some examples of research into assessment may be found in the work of Eglen and Kempa (1974), who examined the concordance of teachers' assessment of practical skills and how that concordance is affected by different assessment procedures; in the work of Firman (1974), who examined methods of assessing Nuffield 'O'-Level Chemistry Options; and in the work of Novick and Avivi (1976), who examined the evaluation of a programmed self-instructional programme in chemistry.

In contrast, relatively little attention has been given to a study of the purely observational phase or to the study of the relationship between observation and the subsequent interpretative process. The only studies found in the literature as relating to this area were those of Ward (1971), Tomera (1974), Dietz and Barufaldi (1975) and Wright (1978).

Tomera's work was concerned with the transferability and the retention of transfer of observation training in science and with the dependence of the ability to transfer on the length of the training period. Dietz and Barufaldi, however, examined the effect that the novelty of an object had on its observability, and they also enquired into whether students compared objects or indulged in separate identification procedures. Wright's work looked into the influence of intensive instruction upon the open exploratory behaviour of students. He used a discrepant film loop, which was problem-orientated, as his method of instruction and found that, over a very short period, i.e., one in which the post-test followed quickly after the instructional session, students

who received specific observational training identified more detail in the post-test than did the control group.

Ward's work was more specifically concerned with chemistry than the other three studies, and examined the effect that different modes of task definition had on the observational attainment of students undertaking a practical observational test in chemistry. He used three different approaches or modes of guidance in the study. The first was called the Open-Ended approach; in it students were given no guidance except for precise manipulative instructions, but were expected to record all the observations they made in the test. The second approach was termed the Partial-Direction approach. Here, the students received specific guidance towards one particular stimulus involved in each reaction and were expected, in addition, to make all the other observations possible. The third, and final, approach used a Check-List guidance system. Here, each student following this mode was supplied with a comprehensive check list of all the possible observations he could make. Thus the students following this approach had the most elaborate guidance available to them. The results showed that the latter group performed significantly better than students in either of the other two groups.

Observation itself may be defined as motivated perception (Mace 1968), and it should be realised that such perception includes the detection of stimuli - not only in the more obvious visual field, but also in the haptic area, concerned with the sense of touch, and in the olfactory area, which deals with the sense of smell. There are, of course, other

perceptual fields, i.e., those concerning the senses of taste and hearing and, in addition, perception covers certain aspects of kinaesthesia, but these are of marginal importance in terms of the type of observation encountered in practical chemistry.

It is tacitly assumed by many teachers that if a phenomenon happens in chemistry (and is known by the teacher to happen) whether it be in the visual, haptic or olfactory area, then the student will make the appropriate observation, record it and go on to use the acquired data in the subsequent interpretative phase. Unfortunately, this is not the case. Mackworth (1970), pointed out that although an observer will always look towards the sources of an external stimulus that interests him, it also stands as a corollary that he will not look at something which does not. In addition, she pointed out that, in the case of a visual stimulus, even if the gaze rests directly on the item to be observed, it does not mean that the student will necessarily notice it, or report it, even if he is searching for it and paying attention to it.

Therefore we need to direct our attention specifically to the act of observation since it serves as a foundation for the subsequent problem-solving phase, and as Molitor and George (1976) pointed out, the quality of data collected determines the direction of the subsequent data analysis.

II A survey of problem areas in chemical observation

It has already been stated that little research has been carried out specifically in this area, and of the observation studies referred to only Ward's was concerned with practical

chemistry, so it is therefore essential to identify those areas of the subject which are problematical.

First, it is pointless attempting to discuss levels of observational competence unless a reliable, standardised test exists to measure such competence. If Mackworth's hypothesis is correct, and this was certainly supported by Ward, who found that under the conditions of the observational test used in the 1971 study, the best level of observational attainment, that of the check-list students, was only 64%; this, therefore, means that under the best conditions used in that research one in every three observations was missed. This, then, would appear to point to two further areas which need to be investigated.

Second, we need to ask the question as to whether observation is, in fact, teachable. The Wright study showed that a period of instruction of a particular type brought about a significant improvement in the standard of observation of detail, but whether this applies to a normal learning process in a school is an open question. Third, an examination of the learning process in the laboratory shows that it is a sequential, hierarchial process; planning leads to manipulation, this gives rise to observation and, finally, an interpretation is made. This process, whilst obviously sequential, is essentially hierarchial in that subsequent steps depend on what has preceded them. Therefore the final step, the interpretation, is vitally dependent on the observational step which precedes it. Thus we need to investigate what effect the possession of observational data of varying levels of quantity and quality can have on the interpretative phase which follows.

For instance, if the observations made by a student are incomplete, then presumably he will have a restricted data base from which inference can be made and conclusions arrived at; on the other hand, if some of the observational information is in fact erroneous and illusory, then this might lead to an uncertain interpretative phase.

Therefore, from what has been said above, we need to investigate three separate, but related, problem areas concerned with observation in practical chemistry, namely:

- i) a re-examination, under more exact conditions, of the effect that different modes of task definition can have on the observational attainment of students measured by means of a standardised observational test;
- ii) whether the use of different modes of training in a school teaching situation leads to different levels of observational attainment; and
- iii) the exploration of the relationship between the quality and type of observational data possessed by a student and his subsequent interpretative processes.

III Research issues involved in the study

We have postulated that this study is concerned with three distinct, but inter-related problem areas; we now look in greater detail at the research issues involved.

a) The design of a standardised observation test in chemistry

The study by Ward (1971), used a chemical observation test to investigate the effect of different modes of task definition on observational attainment, but as this was basically exploratory in nature, no undue attention was paid to the development of a standardised test; however, it was felt that for the work described in this present study, the development of a standardised test was of paramount importance. The major aspects to be considered were concerned with the actual construction of a standardised test. By "standardised test", in this context, is meant a test which, for a given population

offers stimuli in the various perceptual areas, which are comparable in their ease of detectability. In other words, what is aimed at is a test in which all observational tasks have the same facility value.

It was tacitly assumed in the 1971 study that the ease of detection of one particular stimulus was approximately equal to that of another but different one. Thus, for example, the detection of a colour change from blue to red was thought to be of similar difficulty as the detection of a solid dissolving completely in a solvent. In addition, the concept of task complexity used in the 1971 study simply referred to the number of stimuli offered in a particular chemical reaction, again irrespective of levels of difficulty of individual stimuli and possible interaction effects between them.

Therefore, in the present study we need to establish levels of detectability, known as threshold levels, so that eventually a measure of intrinsic detectability of chemical stimuli can be arrived at. Having done that, it should then be possible to design a standardised test of observational ability in which the level of difficulty of stimulus detection of each observable phenomenon is known and where, therefore, task complexity can be thought of in more meaningful terms.

The possession of what amounts to facility indices appropriate to each observable phenomenon will also allow for a more rigorous application of the Partial-Direction mode. In Ward's 1971 study the cueing used in that mode was, as it happened, directed towards stimuli which were easily detectable anyway, and thus it was suspected that not only was the partial-direction approach wasted, but other and, from an analysis of the results, more difficult stimuli were missed since they were in the non-cued observational area.

b) An investigation into whether observation is in fact teachable

In the laboratory, the manipulative and observational phases are essential precursors to the interpretative phase. In terms of improving the quality of the manipulative phase, much work has already been carried out and some of the studies have already been referred to earlier in this chapter, but little has been done to improve observation in the purely chemical area.

It is, however, felt that the forms of task definition used in the Ward study might serve as the basis of three teaching programmes designed to investigate whether the powers of observation of students in school chemistry laboratory situations could be improved. If, also, a form of standardised observation test was available it would then enable the efficiency of the teaching programme to be assessed with some degree of accuracy.

c) The interpretative or problem-solving phase

The Nuffield 'O'-Level Sample Scheme referred to already suggested that pupils shall, as a result of their studies, develop the power of disciplined, imaginative thinking, and since Greateorex and Lister made it clear that this thinking should be based on the results of practical exploration, then we need to examine carefully the interpretation of observational data. Doran (1978), stresses that the type of thinking referred to requires that students should

- i) recognise assumptions
- ii) interpret data
- iii) formulate hypotheses and
- iv) be capable of testing such hypotheses.

In 1958 Inhelder and Piaget used a problem-solving approach, based on a chemical situation, as part of their research, and this was replicated by De Luca (1977) in a more convenient electronic mode, both experiments producing similar results. The problem used was, however, based on data derived from one set of experiments, but in the laboratory the data on which students try to formulate hypotheses and draw conclusions varies both in quality and quantity, so the situation is far more complex.

For instance, if a pupil happens to be faced with a single or even a double stimulus chemical change, i.e., he is expected to observe a precipitate being formed and also to note its colour, then the results of the Ward study would suggest that the observations are likely to be successfully made; but if, for example, a chemical substance is heated, it is a fact that this sort of change can give rise to a far more complex multiple-stimuli situation with the various components competing for the observer's attention, and thus completely successful detection is far less likely to occur. Therefore the quality of the data available to the student in the two instances is likely to be very different, and the interpretative phase in the former case will be based upon a more certain foundation than in the latter.

It is necessary, then, to investigate in an exploratory manner, how students use observational data supplied to them in order to solve chemical problems and how this process depends, if at all, upon the quality of data supplied, be it adequate, inadequate, excessive or erroneous.

Summary and thesis structure

a) Summary

It is the intention of this present study to carry out investigations into three separate but related study areas;

- i) a more detailed and systematic investigation into the effects of different modes of task definition on observational attainment in practical chemistry (for convenience this will be referred to as the Task Definition Study);
- ii) an investigation into the relative effects of the different modes of task definition, when used as the basis for three teaching programmes, on the observational attainment of students (this to be known as the Teaching Study); and
- iii) an investigation of an exploratory nature into the relationship between different types of observational data bases, and the use made of them in the subsequent interpretative phase (this part of the study will be known as the Problem-Solving Study).

As an essential precursor to all three of these investigations, a preliminary investigation into threshold levels (known as the Threshold Study) will first be carried out.

b) The thesis structure

Following this chapter there will be a chapter devoted to a review of relevant literature covering the background to the instrumental development involved and looking at basic theory pertinent to the research.

In chapter three, the overall strategy of the investigation will be considered.

Chapter four will be devoted to the Threshold Study; chapter five to the Task Definition Study; chapter six to the Teaching Study; and chapter seven will examine in an exploratory manner, the Problem-Solving aspect. Finally, chapter eight will present overall conclusions and suggest possibilities for further work.

CHAPTER 2 BACKGROUND TO THE STUDY

I Introduction

In this chapter certain aspects of perception relevant to the study are examined. These include a consideration of how the perceptual systems accept information from external stimulation and how such perception can be modified and developed.

Since observation is inevitably linked to the senses and if these are parts of perceptual systems as proposed by Gibson (1968), we need to examine these systems in some detail. In this study, attention is confined to the observation of chemical phenomena and thus only the visual, haptic and olfactory perceptual systems are of relevance, since the senses of hearing and taste play little part in practical chemistry.

II Perceptual systems involved in the study

a) Organs and receptors

Man is not usually a passive receiver of stimuli, but their intensity can be modified by organs called 'motor'. This means that the receptors may be made to accept more, or less, of the stimulus. For example, if the receptor units in the fingers detect a thermal stimulus, the fingers may, after the initial input has been received, move either to strengthen or weaken the effect of that stimulus. Therefore the fingers as well as acting as receptors have a 'motor' function. This behaviour agrees with Maces' (1968),

definition of observation as motivated perception, where the purely sensory function of a receptor is combined with 'motor' movements to provide modified observation.

The different types of sensory receptors, the 'immobile' part of the input system, are now examined.

Receptors are units which are capable of changing their input into the central nervous system, usually in terms of the change in energy received by them. They tend to register sequences of, and changes in, stimulation rather than the pure energy involved. They are of three types: photoreceptors, mechanoreceptors and chemoreceptors.

Photoreceptors are incorporated into the eye and are of two types, the rods and the cones. They are built into an extremely complex structure with the cones being responsible for colour vision. Mechanoreceptors are found all over the body surface and within it, but it is only with those in the skin and in the underlying tissue that we are concerned. It is reasonable to suppose that when these particular receptors are squeezed, stretched, bent or heated, certain specific events are denoted in the appropriate brain area. Chemoreceptors are found in the nose and mouth area and react to volatile substances with smells.

b) Perceptual systems and related perceptual fields

1) Visual perception

It has been established that the photoreceptors of the eye, together with the 'motor' aspects of eye and head form the visual perceptual system. In terms of a chemical situation, this is concerned with two perceptual sub-tasks, namely colour perception and dynamic perception.

Colour perception

Colour is usually defined in terms of three attributes: hue, saturation, and brightness. Attempts to quantify these have met with a considerable degree of success. For example, hue can be defined in terms of the wavelength of the light involved. The work of Cavonius and Schumacher (1966), which will be examined in greater detail in Chapter 4, relates the ease of detection of lights of various hues to a wavelength function and thus has led to a better understanding of the role of hue changes in colour perception.

Saturation has been defined in terms of the relative proportions of the specific hue and white light by Munsell as long ago as 1905; whilst the work of Hunter (1976) has enabled the luminosity or brightness aspects of both the receptors in the eye and the inherent spectral energies of the different parts of the visible spectrum easier to comprehend. It explains why certain wavelengths are easier to detect than Cavonius and Schumacher's findings would suggest. Their work refers to constant luminosity values across the spectrum and suggests that changes at the blue end of the spectrum should be easier to detect than changes involving an equal wavelength increment in other parts of the spectrum. Hunter found that the yellow-green area is most easily received by the eye and that the yellow-orange region has the highest spectral energy and therefore makes a greater impact by virtue of the higher relative energy change.

Dynamic perception

When an object moves in any way, i.e., in a chemical situation where a stream of bubbles move upwards

through an apparently stationary liquid, a figural transformation occurs. This means that the moving stimulus covers and uncovers its background. Therefore the observation task involved is not simply one of 'detecting a stream of bubbles', but it also involves the perception of a background which also changes as some of it is covered and uncovered.

Therefore we have a situation in which, although the rods and cones react to all stimuli which excite them, the 'motor' action, which can focus on one part of the field of view rather than another, really determines what is observed.

ii) Haptic perception

This involves the mechanoreceptors in the fingers in conjunction with the muscles of the fingers, but the mechanism which initiates the nervous input is not known for certain. According to Nafe (1934), the arterioles in the tissues suffer constriction or dilation; this in turn specifies a thermal event. However the mechanism functions, we are dealing with cutaneous contact which measures the relative temperature of the contrasting surface, and the stimulus is the direction of heat flow at the skin. Certain illusory possibilities arise however. For instance if the piece of material being examined is a metal at the same temperature as the skin, it may well feel colder because of the better thermal conductivity. Changes in skin temperature caused by temperature adaptation can also lead to faulty haptic perception, i.e., the skin can, by contact, adapt itself to the temperature of an object and the initial temperature difference may be negated.

iii) Olfactory perception

In this case there are no convenient reference points such as, for example, the wavelength/spectral energy criteria for light or the difference in temperature in the haptic area. Boring (1942), made some attempt to design a classification system by means of an introspective process. He was looking to chemistry to provide an answer to the essential nature of olfactory stimuli, but it did not seem able to do so. Whilst it is true that pure chemical molecules may often excite the chemoreceptors, it would seem that smells are usually more likely to be caused by complex mixtures of molecules. The specific reaction to individual types of molecules may be incidental. Also whereas when a visual stimulus and, to a large extent, a haptic one, are removed then stimulation ceases, in the case of an olfactory stimulus it can persist simply because of the complex nature of the nasal cavities which can hold or even absorb it.

Thus by their very nature both olfactory and haptic perception can be of a more indefinite nature than visual perception.

III Stimulus-input considerations

a) The characteristics of stimuli

Broadly, it is possible to think of a perceptual stimulus as a goad or spur to action. Certain psychologists consider this a momentary process, but most stimuli one meets in a chemical situation are not in the least momentary. Each stimulus has the following characteristics: it has pattern or form, that is, a simultaneous structure in space, this attribute was referred

to by Gibson as 'adjacent order'; it also has structure in time, or sequence, this he termed as 'successive order'. A stimulus therefore has components of change and of non-change, with the fixed and variable aspects being characteristic of particular stimuli.

b) Types of stimulation

There are two basic types of stimulation. The first, 'imposed' stimulation, involves only receptor activity, but the second, 'obtained' stimulation, occurs when the appropriate 'motor' organ hunts for and brings the stimulus to the attention of the receptors. It is with the latter type that we are mainly concerned, since the efferent impulses, i.e., those from the central nervous system initiated by the primary afferent input, can modify subsequent exploratory action.

c) Levels of stimulus input

Although we cannot, in any perceptual system, separate the activity of the receptor from that of its 'motor' component, it would seem reasonable to assume that, if the latter aspect could be kept constant, then subsequent variations in perception would be dependent upon the efficiency of the receptors and the energy of stimulation. These aspects were considered by Dember (1960), who referred to a detection threshold as that point where a particular stimulus had just enough energy to cause a particular set of receptors to respond. Thresholds may be thought of under two headings, the 'absolute' and the 'difference' types.

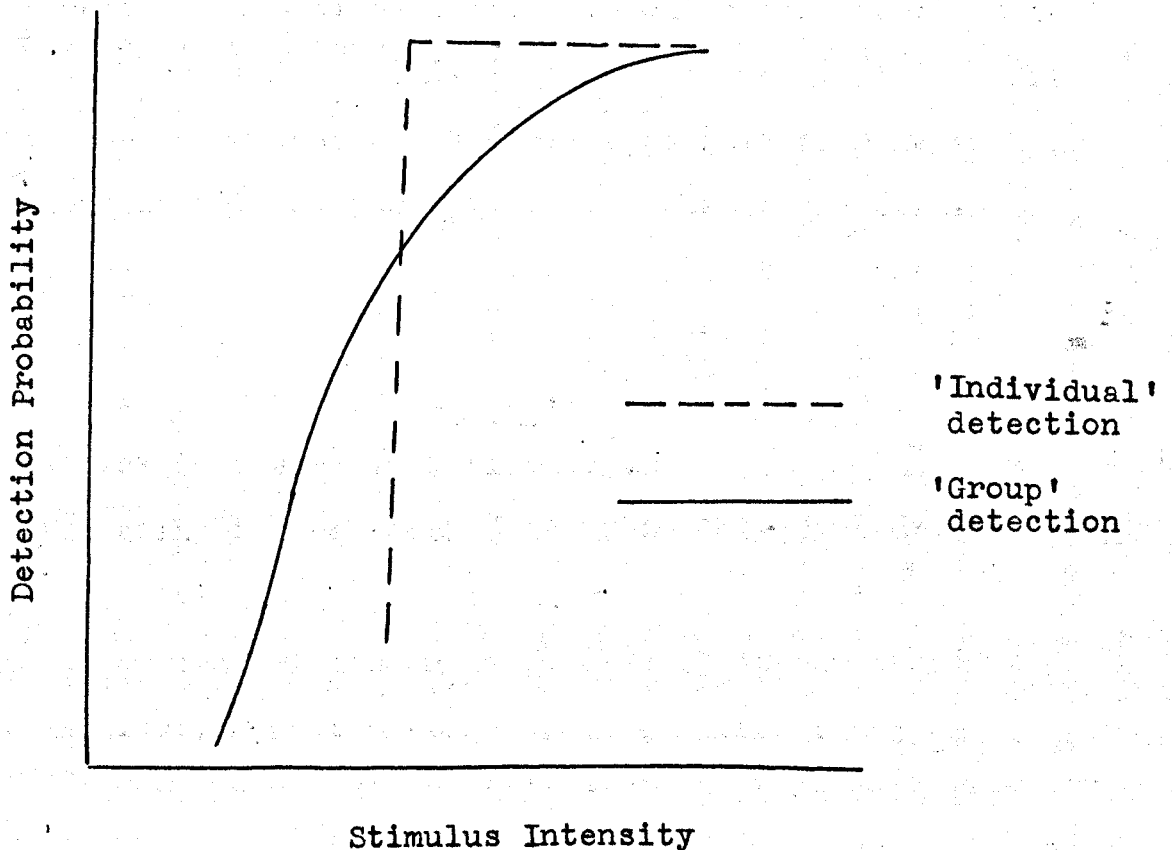
In the former, reference is made to the least amount of energy that a perceptual system can respond to when the stimulus to be detected is imposed on a 'zero background';

whereas, the latter refers to the least change in stimulation which can be detected when the system is already being stimulated. It is clear that in normal practical chemistry, we are concerned almost exclusively with the 'difference' type.

d) Threshold curves

It was discovered that detection thresholds have two main sources of variation: they can differ with time with a particular individual; and they can differ, at a given moment of time, between individuals. The graphs in Figure 1 show what one would expect for a particular individual at a given moment in time, i.e., a finite cut-off point at a certain level of intensity of stimulation and second, what one might expect for a group of subjects displaying individual variations.

Figure 1



If we consider the 'Group' curve, which is of the ogive type, since we have a continuum with no distinct cut-off point, then an arbitrary 'threshold value' needs to be established. This is commonly set at such an intensity that the occurrence of the stimulus is reported accurately 50% of the time and is referred to as the ΔI value. In 'difference' thresholds ΔI is related to the intensity of stimulus before the change (I) and to the change in intensity (dI).

Kristofferson (1954), showed that not only did background intensity and change in intensity affect the threshold, so did the area of stimulus presentation, and an increase in target area compensated for a decrease in target intensity.

e) Multi-stimuli situations

So far we have considered only single-stimulus situations but most perceptual situations are not as simple as that. Hennemann (1957), for instance, conducted experiments in visual perception in which observers had to examine a complex visual field and make judgements on part of it. He found that it was more difficult to make such a judgement if all the perceptual field had to be examined, but if the observer had some form of direction, the process was made easier. However, even with assistance, as more and more irrelevant material was included in the total field, so the task increased in difficulty.

According to Mackworth (1970), the division of attention caused by having to cope with a multi-stimuli situation may have one of two effects on an observer. It may cause greater arousal and therefore enhanced perception; or it may result in the uneven distribution of attention with the parts receiving less attention than they otherwise might have

done in single-stimulus conditions. Sanders (1967), was of the opinion that observers had limited observational capacity which had to be shared out amongst the various stimuli whilst Lawrence and Laberge (1956), suggested that not only was the deterioration in accuracy of the type described by Hennemann a consequence of a perceptual limitation, but was, in addition, a matter of memory. They held that the memory could not hold the influx of several perceptual stimuli for more than a very short length of time, thus memory limitations may affect perceptual outcomes.

How subjects actually approach the problem of a divided-attention situation has also been examined in terms of the way they think, i.e., their cognitive styles, and this aspect is now considered.

Perception and cognitive style

The idea of cognitive style is strongly associated with, and arises from, the area of psychology known as psychological differentiation. Differences exist between individuals in relation to their psychological functioning, and where such functioning appears to take place in relatively stable modes, stylistic qualities may be ascribed to it.

First, cognitive styles are concerned with the form in which cognitive activities are performed, not their content. Second, these styles are relatively stable with respect to time, and research by Witkin et al (1967), suggested that this stability extends over periods of years. Finally, cognitive styles appear to possess bi-polarity, and it has been suggested by Witkin et al (1977), that this feature distinguishes cognitive styles from intelligence and other ability-related dimensions. In one instance, for example,

the possession of an attribute at one end of a bi-polar scale could be useful to a subject in one sphere of activity, whilst possession of the opposite attribute could have its advantages in a different sphere.

Of the various cognitive styles which have been established over the last thirty or so years, the style known as field-dependent/independent is most relevant to the present study. Hennemann's findings on divided attention showed that his population, overall, found the task of visual discrimination more difficult as the complexity of the background increased; but work by Witkin and Asch (1949), showed that when subjects were shown the position of a luminous tilted frame (the 'background') in an otherwise darkened room and were asked to position a rod so that it was in a vertical position, some subjects found it easy while others found it almost impossible. Witkin and Asch found that the former type of observer, described as field-independent, could seek out the important aspect in the complex field acting as background; but the latter type, described as field-dependent, was so influenced by the background that the task became difficult, if not impossible.

Somewhat later an embedded-figures test was developed. In this, the subject was shown a simple geometrical figure. Then he was shown a complex figure and given the directive to locate the simple figure within it. Once again individual performances were markedly different; for the field-independent subjects, the sought after figure emerged quickly, whereas the field-dependent subjects were unable to locate the figure in the time allowed. The subject of the embedded-figures tests

was discussed extensively by Witkin, Oltman, Raskin and Karp (1971), and by Coates (1972), and an extensive review of the subject of field-dependency/independency was given by Witkin, Moore, Goodenough & Cox in 1977. Thus in terms of a multi-stimuli situation the extent to which subjects are field-dependent (one end of the bi-polar scale) or field-independent may well be a relevant factor in determining observational capabilities.

The teaching of observation

It has been made clear earlier in the chapter that one's 'perceptual systems' use mobile, muscular organs in conjunction with passive receptors. Therefore, just as manipulative skills, e.g., handling chemical apparatus, can be taught, so observation ought to be improved by means of a suitable teaching programme. In terms of the reports made on the teaching and measurement of observation in chemistry the literature is sparse. According to Welch (1972), of all research conducted into secondary school science, (30 non-replicated studies), only 20% were chemistry based; and in terms of areas of study only 23.5% was into instructional programmes. Apart from the study by Ward (1971) into aspects of task-definition effects on observational attainment reported in chapter 1, and the researches of Tomera (1974), Dietz and Barufaldi (1975), and Wright (1978), only a paper by Kempa, Palmer and Ward (1971), is relevant to this study. This last mentioned work showed clearly that the observation by pupils of stimuli presented to them in an instructional film was significantly improved by a series of test questions presented before the showing of the film, which acted as cues.

In this latter respect, that of cueing (which was inherent in the Ward study (1971), in that of Kempa, Palmer and Ward (1971), and also in Hennemann's work (1957)), Dorsel and Cundiff (1979) were aware that when such cueing was used continually it could act as an efficient coding device; but it could, on the other hand, become an indispensable crutch. They showed that when extensive cueing was used in a teaching programme, but, unexpectedly, was not used in a subsequent testing situation, performance in the test was significantly worse than when it was

- a) not used at all either in the teaching programme or in testing,
- b) used in the teaching programme and in the testing situation, and
- c) when it was used in the teaching programme with the foreknowledge that it would not be used in the testing situation.

CHAPTER 3 THE OVERALL STRATEGY OF THE INVESTIGATION

In Chapter 1, it was pointed out that the research involved investigations into three aspects of observation in chemistry. These were: i) an enquiry into the effects that different modes of task definition can have on observational attainment (as measured by a standardised observation test); ii) research into the comparative effectiveness of these modes of task definition when they are used as the basis for different observational instruction programmes in chemistry; and; iii) an exploratory study into the ways in which students use observational data as the foundation for the solution of chemical problems.

From a purely practical point of view, it seemed advisable to treat these facets separately, for the following reasons.

Primarily, the investigation into the effects which modes of task definition can have on observational attainment was essentially a 'one-shot' case study. It was therefore compact and it was expedient to think of it as an entity on its own. In addition, as will be described in more detail in Chapter 5, the separation enabled a situation to be developed where the pupils could be kept in ignorance of the details of the chemical systems underlying the reactions they were asked to observe, thus avoiding, to a large extent, the risk of aperception, that is, non-sensory perception. This could arise, for instance, if a pupil knew he was adding a solution of an acid to that of an alkali, in that he could predict on theoretical grounds a heat change, instead of detecting it through his senses.

But in other parts of the study, especially the teaching aspect, it was vital to make sure that pupils were fully aware of the nature of the chemical systems, since in this type of work observation cannot be assessed in isolation from the cognitive aspects of the course. For example, in a reaction which produced an effervescence, the pupils' task was not merely the perceptual one of observing the spontaneous stream of bubbles, but it had cognitive implications in that they had to know what the gas was and how it was prepared.

The first major part of the study, i.e., the investigation into the effect of modes of task definition on observational attainment must, however, be preceded by the development of standardised observation tests, because without these the enquiry into the effect of the different modes cannot be satisfactorily conducted. As will be seen in the following chapter, the essential task involved in the development of standardised tests was the establishment of observational thresholds for the types of stimuli encountered in practical chemistry.

Whilst the task definition study can be conducted in a 'one-shot' case study manner, the teaching study has to be fitted into, as far as possible, a normal existing school framework. The particular teaching programme required teaching to be carried out over a period of two terms and this time requirement was such that this part of the study was conveniently and for practical reasons separated from the task definition study. In addition, as will be discussed in Chapter 6, it was not found possible to conduct the whole of the teaching study in one year, but

it had to be extended over three years, and this added to the impossibility of employing the same population as in the task definition study.

Turning now to the problem-solving investigation of a pilot, exploratory nature which was planned, it was thought essential to have reflected in it the kind of information which would normally be derived by pupils following actual practical exercises; however, it was decided not to use in this part data which had been acquired by the pupils themselves because of the degree of variability expected in their findings, but to use 'standardised' data instead, thus avoiding perceptual variation. Therefore, in this respect no direct laboratory involvement was needed and thus it became independent of direct laboratory involvement. This meant that the problem-solving part of the study would be pursued if necessary, with a population different from that used in the other parts.

An additional reason for adopting the broad strategy just indicated for the overall pursuit of the investigation, i.e., to employ separate populations, was the fact that the work had to be carried out over a number of years on a part-time basis. No single population could thus have been used for the whole of the investigation. The use of separate populations therefore became an expediency, but one which does not in any way invalidate the research as a whole, in terms of its coherence and purpose.

CHAPTER 4 THE THRESHOLD STUDY

The purpose of this chapter is to describe in detail the design of the investigation, its methodology and administration, and then to present the results obtained with relevant discussion.

Introduction

Prior to the undertaking of the task definition study, some kind of standardised observation test was required, but the development of this was basically impossible unless one knew something about the intrinsic levels of difficulty associated with observational tasks; that is, one must be aware of the item facility of each observational task in a similar way that one is aware of the difficulty of, say, a multiple choice item as expressed by its index of difficulty.

In the context of observational work the appropriate criterion would seem to be that of an observation threshold, i.e., detection limits. These are limits below which an observation ceases to be detectable.

In terms of the types of observation made in chemistry this might mean that when two solutions react together to produce heat, i.e., give a thermal change, a point is reached at which the concentrations of the solutions have been so reduced that the resulting thermal change is no longer detectable. Likewise in the case of an olfactory sensation, the concentration of molecules in the atmosphere is so small that they do not provide sufficient stimulus for one's sense of smell. Therefore a study of observation thresholds, in order to establish these limits, is an important prerequisite

to the design of an observational instrument.

As well as being essential to the development of standardised observational tests, the study of detection thresholds has some validity in its own right for the following reason. In teaching, it is not unusual for teachers to make the assumption that any observation which can be made by pupils will be made by them. If from one's aperception of a chemical situation it is known that a temperature change must occur, then it is sometimes assumed, in fact, that pupils will be sufficiently sensitive and alert to notice it. We really do not have any information about when observations are possible from the pupils' point of view, and this study will go some way to filling this need. With the information obtained it should then be possible to design experimental investigations and assess them with a greater certainty that what is presented for observation can in fact be observed, since it can be presented at above threshold level.

II The scope of the investigation into detection thresholds

For the purpose of this study three main perceptual areas were accepted as being relevant to chemical situations. The first concerned visual perception, and situations encountered here included the appearance of, or change in, colour, the appearance or disappearance of solids and the appearance of gases produced by effervescence. The second area involved haptic changes, requiring the pupils to use the sense of touch to detect heat changes arising from chemical reactions. The third area involved olfactory changes, i.e., changes in odour.

a) Single stimulus situations

In classical threshold studies, which fall within the domain of experimental psychology, it is customary to consider only single perceptual stimuli. In the context of a chemical situation, this could perhaps, be exemplified by a reaction in which the only observable change is a thermal one; the detection of an observational threshold would then entail finding the magnitude of the thermal change at the point at which it ceased to be detectable. Such thresholds can be established with a fair degree of accuracy, but it must be acknowledged that variations can arise from two sources.

As was pointed out in Chapter 2, detection thresholds can vary from person to person. Thus, one subject may be able to detect a thermal change at a lower level of intensity than can another, also, a subject's detection threshold for a given stimulus may not be constant from one instant to another. Both these factors can affect the accuracy and reproducibility obtainable in threshold determinations. However, for a reasonably large population, good 'average' threshold values can be determined for which errors due to personal differences are minimized.

b) Multi-stimuli situations

In practical chemistry, it is a common occurrence that two or more observable stimuli appear simultaneously. For instance, if a solution of silver nitrate is added to one of sodium chloride not only is a precipitate of silver chloride formed, but there is also an evolution of heat.

It is conceivable that when two or more stimuli occur

simultaneously, the detection threshold relating to one of the observations is affected by the presence of the other perceptual stimulus or stimuli. Since such interactions can have major implications for the development of standardised observational tests, the study of observational thresholds was so designed that it embraced

- i) single-stimulus thresholds, and
- ii) thresholds of one stimulus in the presence of another.

Investigations were carried out for a wide range of different chemical situations using the techniques described in the next section of this chapter.

III The determination of threshold levels

This involved examining the ways in which stimuli might be presented to the observers and, in addition, modes in which the students could inform the experimenter whether detection had taken place.

(a) Methods of stimulus presentation

There are two main approaches to the presentation of observational stimuli. The first is known as the constant-stimulus method and the second as the method of limits.

In the first, subjects are required to report on the presence or absence of a particular stimulus in situations in which the magnitude of the stimulus is fixed at values to either side of the expected threshold value. For each situation, the intensity of the stimulus is kept constant throughout the period of observation; hence the term 'constant-stimulus method'. In the method of limits, this latter requirement is not fulfilled: the intensity of the stimulus is deliberately changed by the experimenter in the course of the observation until it ceases to be

discernable to the subject, hence the term: 'method of limits'.

The method of limits was not thought to be suitable for this particular research and thus the more convenient constant-stimulus method was adopted. The one exception to this was for the determination of the threshold of smell detection, where rigorous use of the constant-stimulus method was hardly suitable for this part of the investigation.

b) Modes of student response

Two basic modes can be used to inform an experimenter if detection has taken place. These may be described as

- i) the Yes-No response mode and
- ii) the Forced-Choice mode.

i) In the Yes-No response the subject has to decide about the presence or absence of a stimulus when it is presented at a given level of intensity and simply made the response 'Yes' if it seems to be present and 'No' if it seems to be absent.

ii) In the forced-choice mode, however, the subject has to produce an independent description of a change that he or she identifies.

Blackwell (1953), comparing the two response modes found observational thresholds determined by the forced-choice mode to be more reliable and lower than those obtained by the Yes-No mode. This is principally because the forced-choice mode required an independent description of the observed changes to be made, thus enabling the validity of the reported observations to be checked. By contrast, in the Yes-No mode, the researcher has no way of checking whether the responses given by the subject are genuine or whether they are the result of guesses. The researcher can, however, assess the degree to which guessing has occurred from 'blank' situations deliberately included in the observational test.

However, the forced-choice has a disadvantage in that the

requirement for the subject to provide an independent assessment of the observed changes demands that he should be able to verbalise the observed phenomenon. For example, if a subject observes a colour change from, say, red to mauve, but is not familiar with the nuances of coloration in the red region, he would fail to report the change accurately because of his unfamiliarity with the "right word".

Dember (1960) asserts that the conventional employment of the two modes yields roughly equal threshold estimates and points out that the Yes-No mode has obvious practical advantages. In general the Yes-No mode is less time consuming than the forced-choice mode. For every response collected by the latter several can be obtained by the former. This also gives the Yes-No response mode superiority over the forced-choice mode on theoretical grounds in that it enables a series of rapid measurements to be made, thus avoiding the influence of changes in sensitivity with time, on threshold measurements.

Bearing in mind the limited time available for the determinations, and the age and ability range of the population available, it was decided to use the Yes-No mode, with the inclusion of 'blank' situations. This avoided the need to assume competent verbalisation and enabled a check to be made on the degree of guessing. It also enabled a larger number of observations to be made in each set of threshold determinations than if the forced-choice response had been used.

In principle, then, the detection of threshold values involved the subjects in carrying out simple chemical tests, usually by the mixing of two solutions in correct proportions and noting for which of the reactions the appropriate stimulus could be detected and for which it remained undetectable. In the context of the present study, thresholds were determined for

the following range of stimuli, presented singly and in multi-stimuli situations:

- | | |
|--|------------------------|
| i) colour changes | iv) solution changes |
| ii) precipitation changes | v) haptic changes |
| iii) changes involving the redissolution of precipitates | vi) effervescences and |
| | vii) olfactory changes |

- c) A consideration of the choices of combination of stimuli for use in multi-stimuli situations

As far as the design of multi-stimuli situations was concerned, three combinations involving two stimuli each present themselves in the broad context of the study. These are:

- i) visual with haptic
- ii) visual with olfactory and
- iii) haptic with olfactory

In each case two possibilities arise, namely that the first mentioned stimulus is made the variable one whilst the second stimulus remains constant, and vice versa.

Considering the sequence in which observations would normally be made in chemical situations, it may be argued that whenever olfactory changes are involved in a multi-stimulus situation, they are detected at a time different from that of the detection of a visual or haptic stimulus. Usually this means that olfactory changes are detected at a later stage than either of the other two. Therefore, in a combination of an olfactory change with either a haptic or a visual one, the changes may be regarded as two single-stimulus changes in sequence.

The consequence of this is that the multi-stimulus situation should concern itself with changes that occur more or less simultaneously. The only type of situation fulfilling this condition is that of a visual stimulus in combination with a haptic one, and the investigation was therefore limited to this particular situation. To simplify matters still further, only one of the several possible visual changes was considered in this context, namely effervescence.

IV The development of the test items

This will be considered according to the perceptual field or sub-perceptual field involved.

a) Haptic changes

These were produced by the mixing of aqueous solutions of acids and alkalis. The solutions used were colourless, and a temperature change was the only detectable observation. It could, of course, be argued that the volume change obtained upon the mixing of two liquids is in itself an observable phenomenon. If this viewpoint were taken, then the change brought about in the present situation would not be of the "single-stimulus" type. However, since the pro-forma used requested pupils to mix the liquids, it was felt that pupils would interpret the request to 'observe changes' only in relation to phenomena other than the mixing of the liquids. Therefore the changes brought about by the mixing of acid and alkali solutions were considered "single-stimulus" changes without distractions.

The exercise required pupils to state whether a detectable temperature change had occurred and to report their findings on a pro-forma, which also gave them essential manipulative instructions. (The details of the chemicals used and a copy of the pro-forma are shown in Appendix A i).

In this determination and in all other threshold determinations except the olfactory one, the stimuli were presented in a random order in terms of their intensities so that the conditions of the constant stimulus method might be met. In the determination of the olfactory stimulus, to be discussed in part d ii) of this section, the constant stimulus method was modified.

b) Solids changes

There were three separate investigations within this perceptual area. The first dealt with the detection of

precipitation; the second with the redissolution of a precipitate and the third with the dissolving of an added solid.

i) Precipitation thresholds

As in the previous determination, it was essential that this should be a single-stimulus change, i.e. only precipitation should take place with no other distracting changes. Therefore white precipitates were used to avoid colour changes, and no thermal or gaseous change was present. The precipitates produced were mainly those of insoluble lead compounds, but in one instance an insoluble calcium compound was produced.

The pupils were asked to state whether precipitation had taken place and to record their findings on the pro-forma provided, which also gave them essential manipulative instructions. It was made clear to the pupils that the degree of precipitation was not important, only whether precipitation took place.

The details of the chemicals used and a copy of the pro-forma are shown in Appendix A ii).

ii) Thresholds for the redissolution of precipitates

This refers to situations where a solid, present in suspension in a liquid from which it has been precipitated, can, as a result of a second reaction, undergo total or partial redissolution when excess of the precipitating reagent is added.

The reaction chosen for this investigation was the redissolution of the amphoteric zinc hydroxide, precipitated by means of sodium hydroxide solution, in excess of the same reagent. The solutions were decided upon after careful study of the zinc hydroxide/sodium hydroxide system, to give a range of experimentally reproducible redissolutions. The pupils were required to report whether any precipitate which was formed redissolved and to report this on the pro-forma provided. The pro-forma was similar in form to those used in the previous experiments and a copy of it,

together with the identities of the solutions used, is shown in Appendix A iii).

iii) Thresholds for the dissolution of added solids

Simple chemical experiments involving solids often require the solubility of a solid in water, or some other solvent, to be judged qualitatively. Typical judgements to be made are to find out whether the solid is insoluble or partially or completely soluble. In this part of the research it was decided to ask pupils to shake separate quantities of solid sodium chloride of known mass with solvents which were either water or solutions already containing sodium chloride. The pupils were required to assess, by eye, how much solid was added, shake the tube containing the solution and solid for fifteen seconds and reassess the quantity of solid remaining. They were then required to report on the pro-forma whether any of the solid had dissolved. The details of the chemicals used and a copy of the pro-forma are shown in Appendix A iv).

c) Threshold determinations in the area of colour perception

The discrimination of changes of colour in practical chemistry can be problematical in two ways. First, and by far the more important, there are those discriminations associated with definite changes in the spectral characteristics of colours to be observed, that is, changes in hue. This particular type of change would be involved if a green solution turned yellow. Second, changes in colour intensity which are dilution or concentration effects have to be considered. These are known as saturation changes. As this type of change is relatively unimportant in chemistry, it was decided not to include saturation-perception thresholds in this study.

In the design of the observational test items relating to colour-perception thresholds, it was thought to be important to take cognisance of the work of Cavonius and Schumacher (1966).

These authors report that the discrimination of changes in hue depends first, on the actual magnitude of the change (which can be expressed in terms of the wavelength change involved), and second, on the actual colour itself (which may be specified in terms of the region of the spectrum where the change takes place).

For the first effect, they found that the larger the actual change in wavelength the easier it is to detect that change; for the second factor, they report that changes in hue for a given wavelength change are easier to detect at the blue end of the spectrum than at the red end. This applies strictly to a condition of equal luminosity used throughout, a condition which, in terms of the present investigation, is impossible to achieve.

The implications of the Cavonius and Schumacher findings for the present study are that the determination of threshold values for hue changes cannot be confined to a single change, but must sample a wide range of colour changes spanning the visible spectrum. In order to achieve this it was decided to use a solution of Universal Indicator in conjunction with suitable buffer solutions, thus causing the appropriate desirable hue changes.

In the actual design of the experiment the following hue changes were investigated:

- | | |
|------------------|----------------------|
| i) red/purple | v) yellow/orange |
| ii) green/purple | vi) green/yellow and |
| iii) green/red | vii) blue/purple |
| iv) red/yellow | |

In each case, the pupils were supplied with a solution showing a particular hue and were asked to add to this solution another, specified, solution and report whether a colour change had taken place.

Details of the materials used and a copy of the instruction and report form are given in Appendix A v). It should be pointed out that in this part of the study all pupils were first checked for colour blindness before the administration of the threshold tests.

d) Perception thresholds in systems involving gases

Of all the possible changes pertinent to this perceptual area, those encountered most frequently in school chemistry are the detection of effervescence (i.e. the evolution of gas from a solution) and the detection of odours. Only these two aspects of gaseous changes were thus examined.

i) Threshold values in the detection of effervescence

The effervescences were caused by the reaction between solutions of an acid and of a soluble carbonate. Thermal changes were kept well below their threshold value so that the situation was in fact a single-stimulus only. Pupils were required to report whether effervescence occurred when the reagents were mixed. Details of all solutions used and a copy of the instruction and report pro-forma are given in Appendix A vi).

ii) Olfactory changes

Generally, gases with smells have a tendency to be poisonous, and this precludes their use in a school situation for obvious reasons. However, it was found possible to investigate the disappearance of a smell, that of ammonia, starting at the sort of concentrations normally found in 'bench' ammonium hydroxide solution, i.e. about 3-4%. Pupils added, drop by drop from a burette, a solution of sulphuric acid to a fixed volume of ammonium hydroxide solution. After each addition they were asked to smell the tube containing the ammonium hydroxide solution. When they felt that the smell had disappeared, the burette reading was taken and recorded. This experiment was then repeated and the mean of the two results was calculated.

The details of the chemical used and the instruction and report pro-forma are shown in Appendix A vii).

It should be noted that whilst this was a constant stimulus method in that pupils examined a series of smell producing situations each of which gave off a constant smell, the

intensities were not randomly presented at either side of the expected threshold, but instead were gradually reduced in intensity from above threshold to below it.

e) Threshold determinations in multi-stimuli situations

As was indicated on page 34 of this section, only one system was chosen for the examination of threshold variability in multi-stimuli situations. This was the combination of the visual observation of an effervescence and the haptic detection of a temperature rise.

The experiment was designed in such a way that the magnitude of one of the changes underwent variation whilst the other remained at a constant level. The particular system chosen for this investigation was that of aqueous sodium hydroxide, aqueous sodium carbonate and dilute sulphuric acid. The magnitude of the thermal change could be adjusted by the choice of appropriate concentrations of acid and alkali (treating sodium hydroxide and sodium carbonate together); the amount of effervescence obtainable from each experiment was adjusted by the concentration of sodium carbonate that was used. Pupils were asked to direct their attention to the detection of both an effervescence and a thermal change. Full details of the chemicals used together with copies of the proformas and instruction sheets for the two aspects of this part of the investigation are given in Appendix A viii). (Variable Effervescence - Constant Thermal) and A ix) (Constant Effervescence - Variable Thermal).

It should be pointed out that for these particular investigations different groups of pupils were used for each subsection and that both populations were different from the one used in the single-stimulus investigations. This was done in order to avoid any apercception resulting from participation in the other experiments.

Administrative details concerning the threshold studies

a) The population used in the study

This was dictated by two factors. First, since the research had to be carried out in the framework of normal school chemistry teaching, it was not possible to use fourth-year students, the population to be used for the 'one-shot' task definition study, since their examination requirements and the time required to be spent investigating several different threshold values were not compatible. Second, it was deemed advisable to use as large a sample group as possible, so that the results might be as representative as possible under the circumstances. For these reasons pupils in the third year of the author's school were used as subjects for this series of investigations. This part of the study commenced in March 1974 and was completed by February 1977. During this time, the experimental work required to measure thresholds was fitted into the normal chemistry curriculum. The subjects were aged between 13.0 and 14.0 years and at the beginning of the investigation were drawn from a grammar school population, but after September 1974, the school became comprehensive. The populations used included boys and girls.

b) Operational conditions of the threshold study

To enable precise mixing of solutions in all these investigations to take place all pupils were supplied with test-tubes of identical size and wall thickness. This also ensured that no variations arose from differences in target area, i.e. the size of the object to be observed, since Kristofferson (1954), discovered this to be a factor in determining thresholds.

The test-tubes were clearly marked at the 1" and 2"

levels, since the instructions required to mix solutions in terms of these specific depths.

All solutions were identified by code letters so that knowledge of the actual identities of the chemicals was denied to the pupils and thus aperception (deciding what could happen, given the identity of the reactants) was minimised.

It was, however, made clear to the pupils in all the investigations what the particular object of each experiment was, be it visual, olfactory, haptic, single or double. The tests were administered under examination conditions, but without a time limit. Results and findings are given in the following section.

Results and discussion of the threshold study

Introduction

When a stimulus is presented at such a level of intensity that it can be discerned by an observer, we may say that it has been presented at above-threshold level. Since threshold values vary from person to person (within relatively low limits), some broad criterion is needed as to what constitutes a general threshold value for a particular kind of observation. Following examples described in the literature, we may define as an arbitrary threshold that magnitude of a stimulus at which it is successfully discerned with 50% probability. In other words, the lower limit of acceptable observability may be put at the intensity value of a stimulus if 50% of the population fails to observe it. It is this particular critical value which, in this part of the study, is being determined for different types of observations.

As indicated before, four types of observation were studied in single-stimulus situations:

- a) Haptic perception
- b) Perception in the solids area
- c) Colour perception and
- d) Perception of changes involving gases

In addition, a study of a multi-stimuli situation, involving haptic and visual changes, was also undertaken.

First, the results from the four single-stimulus thresholds studies are presented and discussed. Thereafter, the results from the multi-stimuli study are given.

Single-stimulus threshold studies

The particular chemical reactions used for the conduct of these investigations have already been referred to in Section IV, and thus no further details need be given here. All that should be stressed again is that the reactions were so chosen that, from the observer's point of view, only one observation could be made and needed to be made.

a) Haptic perception thresholds

The study of haptic perception is limited in this research to the detection of thermal changes, i.e. finding out whether a particular chemical system underwent a discernible temperature change upon reaction.

The temperature changes were brought about by mixing colourless solutions of acids and alkalis, and temperature changes over the range of 0.5°C to 15°C were used. The results are summarised in Table 1 and illustrated in Figure 1. The percentised success rates given in the table represent the extent to which the thermal changes were correctly identified by the pupils, using the Yes-No response mode.

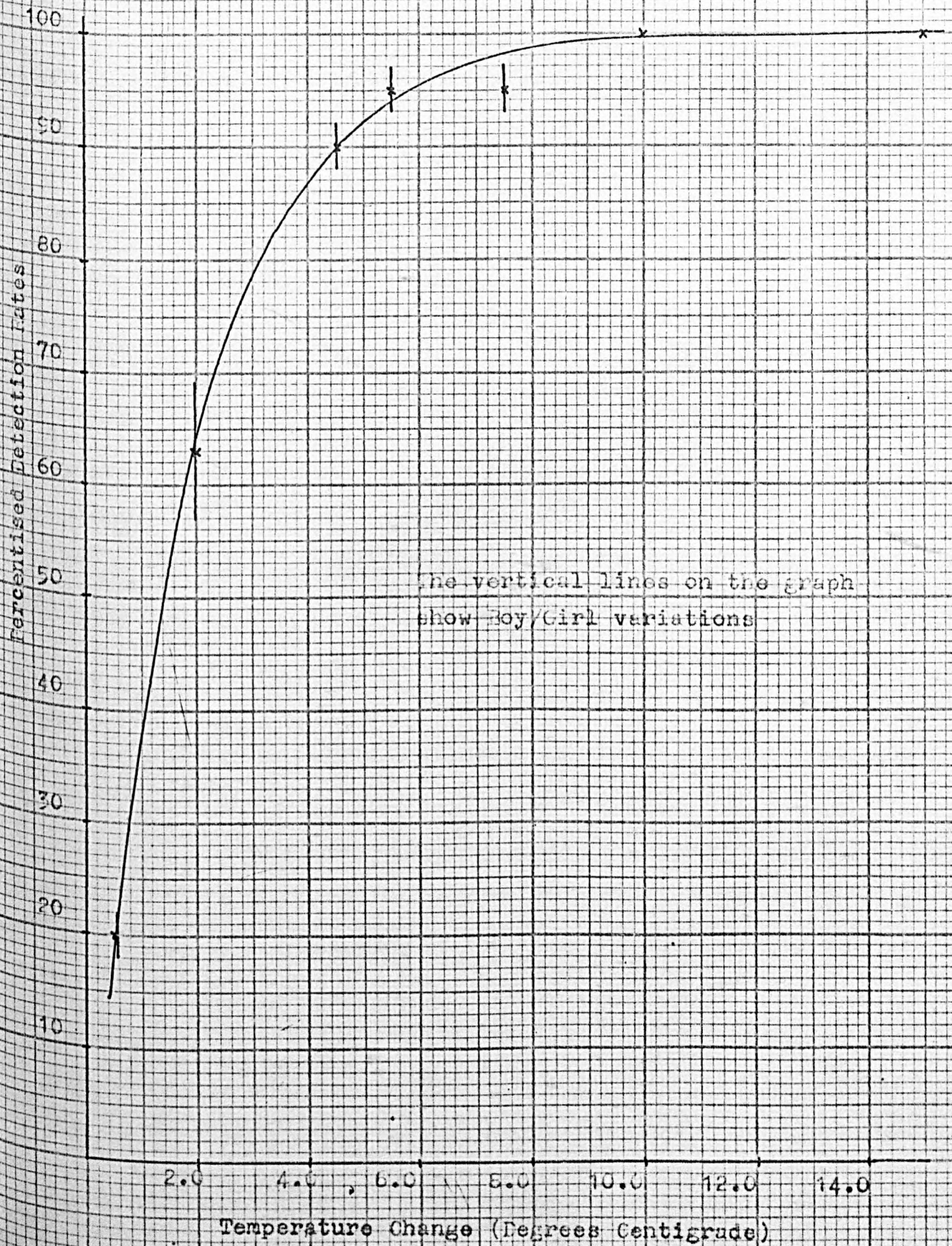
Table 1

Percentised success rates obtained in the detection of thermal changes of different magnitudes

Stimulus Intensity (Temperature change) in °C	Percentised success rates		
	Total population n = 60	Boys n = 28	Girls n = 32
15.0°C	100	100	100
10.0°C	100	100	100
7.5°C	95	93	97
5.5°C	95	93	97
4.5°C	90	88	92
2.0°C	63	57	69
0.5°C	20	22	18

Figure 2

Graph showing the variation in the percentage of students detecting a haptic change with the magnitude of the thermal change (Total population)



To examine whether any significant difference existed between the observational performance of boys and girls, scores on this test were calculated by awarding one mark for each 'correct' temperature change identification (irrespective of intensity values). Mean scores and standard deviations were then calculated for boy and girl populations respectively. The results obtained are shown in Table 2.

Table 2

Mean scores and standard deviation obtained by boys and girls respectively on the thermal threshold test (maximum score = 7).

Population	Mean Score	Standard Deviation
Boys	5.43	0.86
Girls	5.69	1.07

A t-test applied to the mean scores gave a value of 1.01, which does not reach significance at the 0.05 level. Thus no sex differences were found to exist in this case.

There is no a priori reason why there should be any differences in observational attainment of boys and girls, and the present finding is entirely in agreement with that of Smith and Schroeder (1978), who found that, in terms of spatial perception, there was no difference between the sexes. Accepting this as a finding of general validity, one is justified in abandoning any further examination of sex differences in the observational field and to treat the populations as a single one regardless of the sex of the pupils. This policy has been adopted throughout the following sub-sections.

If one accepts the 50% criterion for detection thresholds, then that for the perception of temperature change was found

to be approximately 1.4°C . This value applies with certainty only to room temperature (20°C) since at other temperatures different detection thresholds will apply, because the 50% detection value (the ΔI value referred to in Chapter 2) is related to the intensity of the stimulus before the change (I) and to the change in intensity (dI).

b) Perception thresholds in the solids area

The study of solids perception in this research covered three aspects related to the appearance or disappearance of solids from a liquid. These are:

- i) precipitation thresholds
- ii) thresholds relating to the redissolution of precipitates and
- iii) thresholds for the dissolution of added solids

i) Precipitation thresholds

The precipitates to be observed were caused by mixing solutions which gave rise to insoluble products. The precipitates were of varying degrees of intensity, and a quantitative estimate of the magnitude of each precipitate was obtained by letting the precipitate, which was formed from 8 cm^3 of reactants, settle for twenty four hours under gravity and then measuring its depth in mm. The depths used, and the percentised success rates are summarised in Table 3 illustrated in Figure 3. The success rate data given represent the extent to which the precipitations were correctly detected by the pupils.

Table 3

Percentised success rates obtained in
the detection of precipitation

Stimulus intensity measured as precipitate depth (mm)	Percentised success rate
0	91 *
0.5	24.5
1.0	100
2.0	98
3.5	100
6.0	100

Total population = 78

* For this example, with no precipitation, the correct response was no.

Accepting the 50% criterion for detection thresholds, then that for precipitation detection is reached when the precipitate depth, obtained after twenty four hours settling is approximately 0.6 mm. However, the results also indicate that as long as a reasonable quantity of precipitate is formed, i.e., a quantity which after settling provides a readily recognised deposit, pupils have little difficulty in detecting its presence; but when the quantity of precipitate is so small that it produces a diffuse cloudiness rather than a genuine turbidity then pupils encounter difficulty in deciding whether precipitation has taken place.

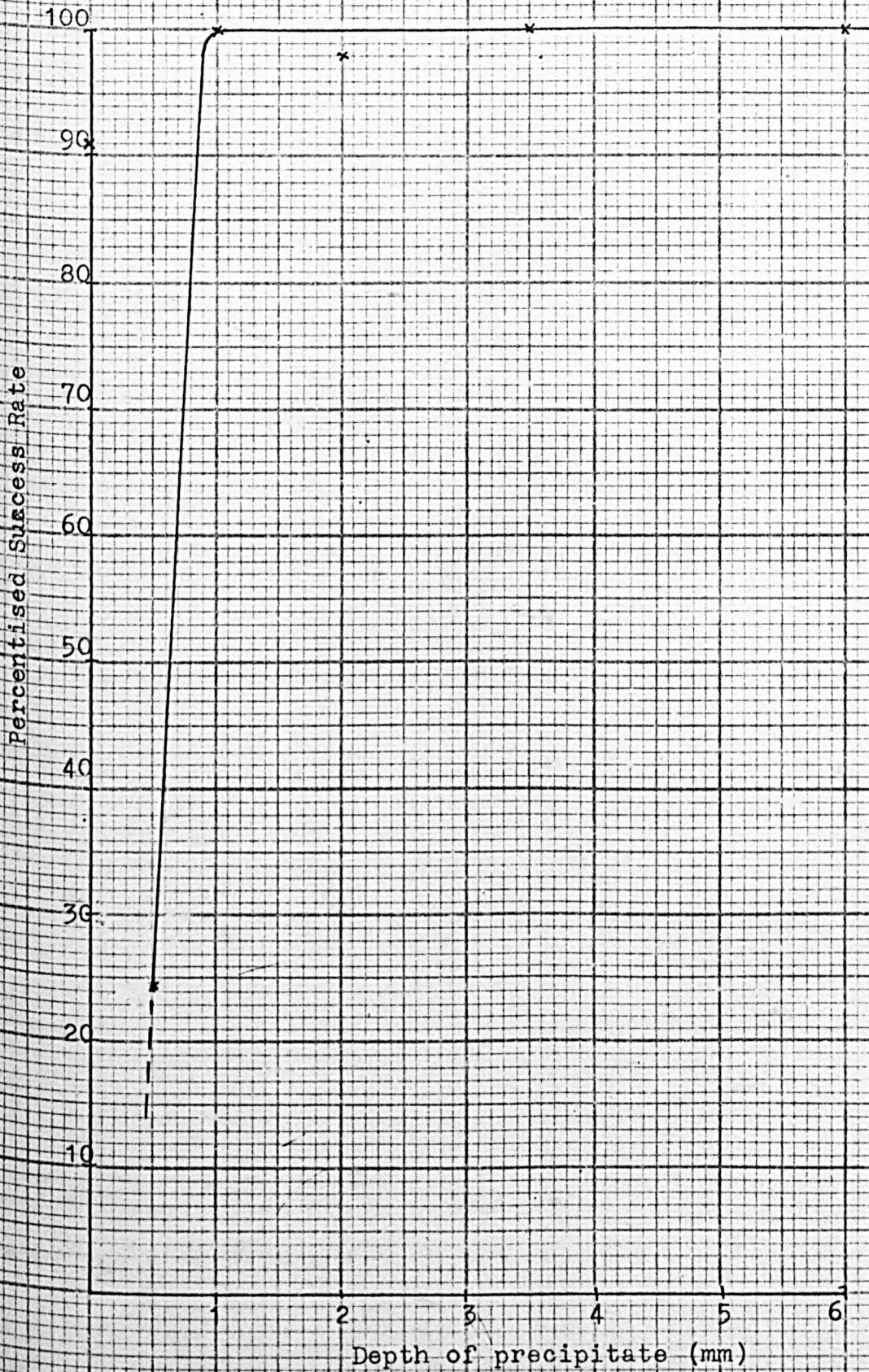
For practical purposes, a mass of precipitate forming a deposit of about 1 mm or more in 8 cm³ of solution should

generally prove detectable by the majority of pupils, but this is a semi-quantitative measure rather than a fully quantitative one, and the exact nature of the precipitate may cause variation in success levels but certainly at values of precipitate depth below 1 mm, the detection rate falls off very sharply.

It is of interest to note, in passing, that some moderate error rate was found for instances in which precipitation was completely absent. What caused the 9% of the population to report the appearance of these precipitates is uncertain, but suggestibility could be one explanation.

Figure 3

Graph showing the relationship between Stimulus Intensity and Percentised Detection Rate for a precipitation change



ii) Thresholds relating to the redissolution of precipitates

Precipitation and subsequent redissolution were brought about by the use of solutions of sodium hydroxide and zinc sulphate. Pupils were told the precipitate would appear, and their task was to decide whether the precipitate of zinc hydroxide dissolved in the excess aqueous sodium hydroxide. The stimulus intensity in this instance was derived from the % redissolution of the original precipitate. The results in terms of % redissolution and detection rates are shown in Table 4 and displayed graphically in Figure 4.

Table 4

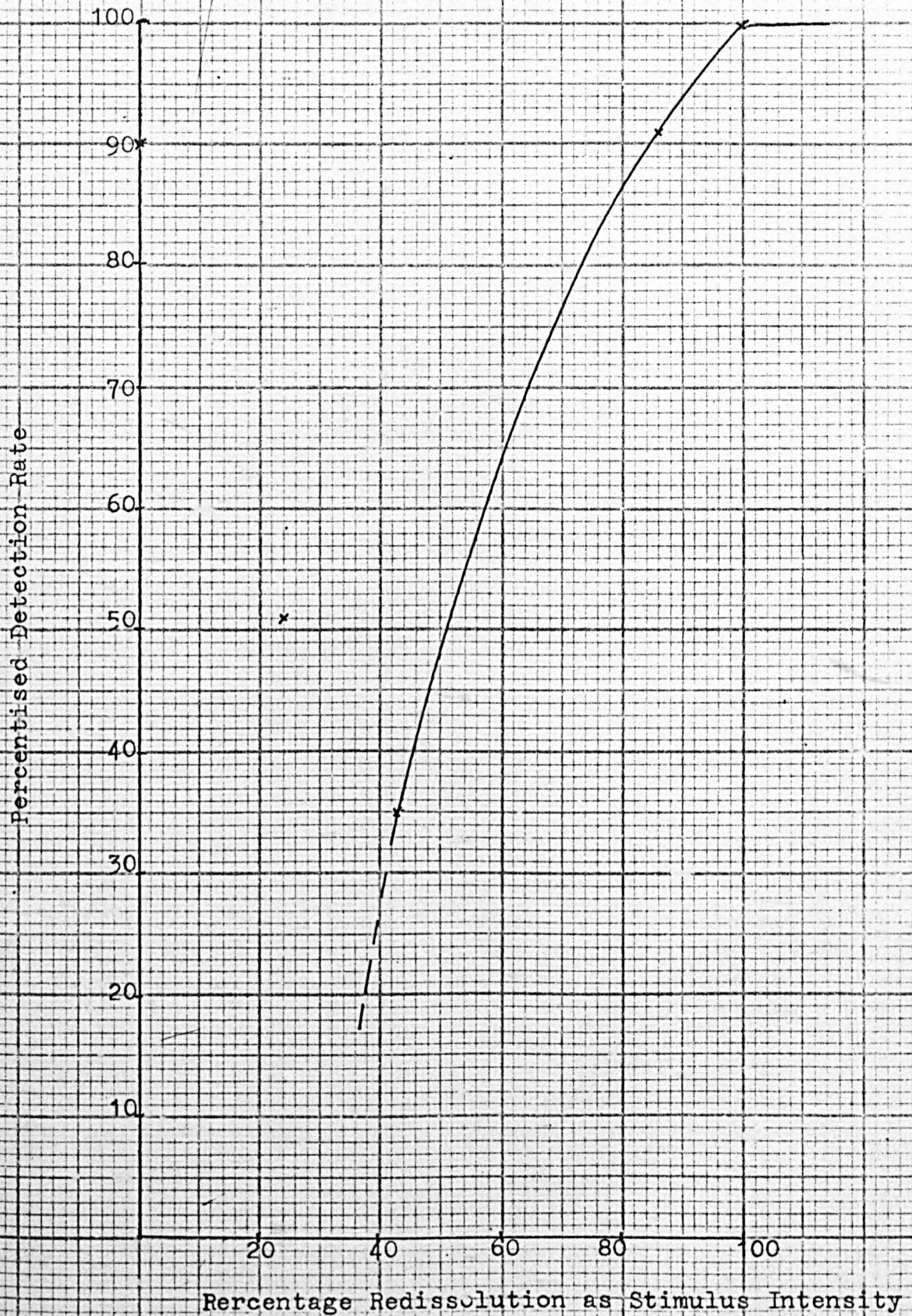
Percentised success rates for the detection of precipitate redissolution

Stimulus intensity (% redissolution of precipitate)	Percentised Detection Rates
100	100
86	91
43	35
14	51
0	90

Population Sample n = 71

Figure 4

Graph showing the relationship between Stimulus Intensity and detection rate for a change involving the redissolution of a precipitate



These results reveal an interesting pattern, in that at moderate or low redissolution values pupils evidently encountered difficulties in deciding whether the precipitate redissolved. It would appear that in these instances the decision became more a matter of guesswork, with a 50-50 probability of being correct. The arbitrary threshold value would appear to be represented by the point where there was approximately 55% redissolution, but it must be admitted that only in cases where redissolution was complete or nearly so did judgement become at all certain. Likewise a similarly high degree of success was obtained when there was no redissolution.

These findings clearly demonstrate that the recognition of the partial redissolution of a precipitate is rather difficult and that obtaining the correct answer under laboratory conditions may be a matter of guesswork. Hence in spite of the arbitrary 55% redissolution value, one would advocate that situations which involve partial redissolution should be avoided in the construction of a standardised observation test.

iii) Thresholds for the detection of the dissolution of added solids

This study was implemented by requiring the pupils to shake a measured quantity of sodium chloride with solutions already containing different concentrates of the salt. This produced situations in which different proportions of the added solid dissolved. The results of this experiment are shown in Table 5 and illustrated graphically in Figure 5.

Table 5

Success rates for the detection of the dissolution of a solid in a solvent, expressed as percentages.

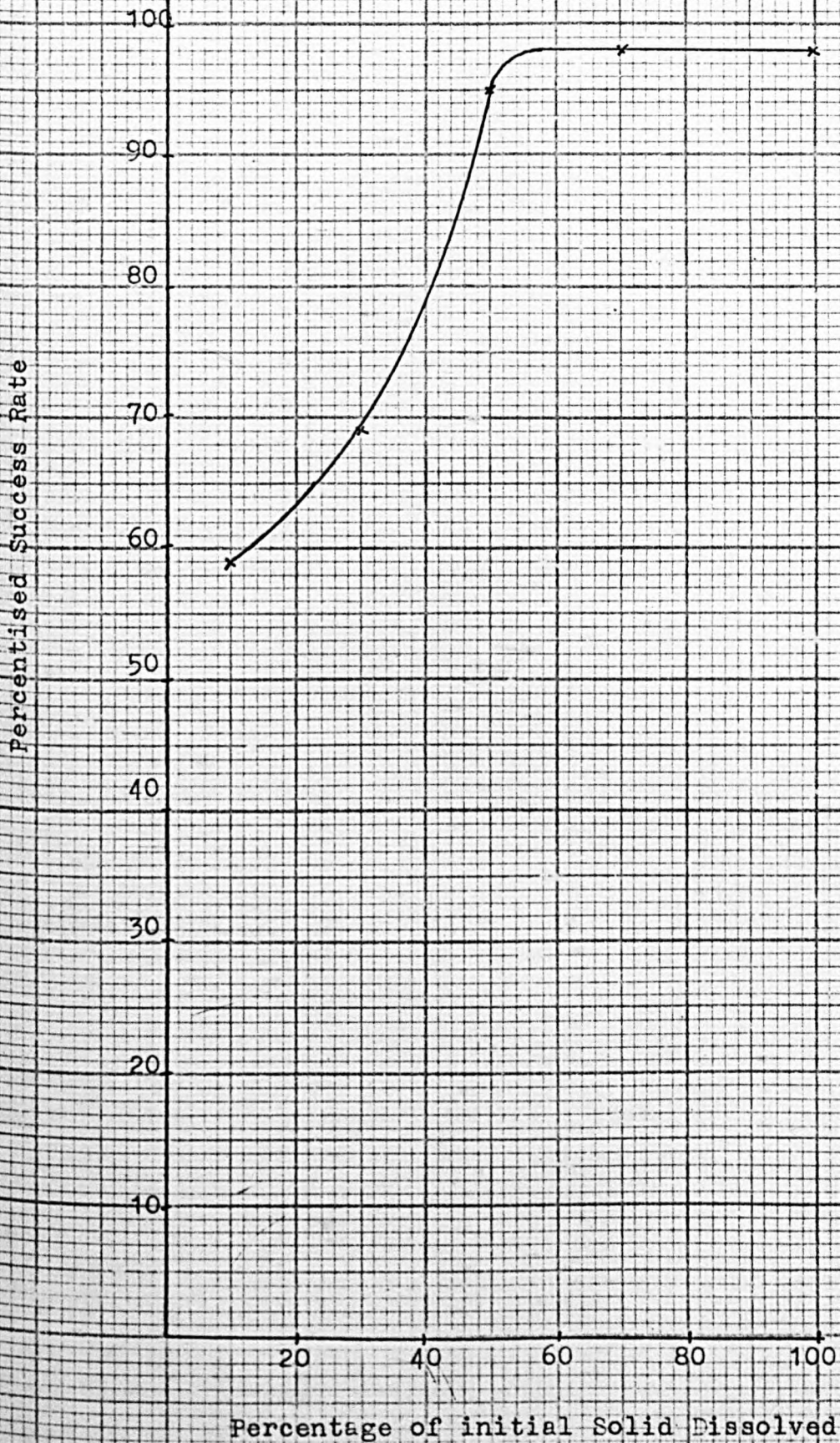
Height of solid remaining after dissolution (mm)	Percentage of solid dissolved	Percentised detection rate
9	10	59
7	30	69
5	50	95
3	70	98
0	100	98

Initial height of the solid = 10 mm

Population = 58

Figure 5

Graph showing the percentised success rates in detecting the dissolution of a solid to various degrees



It can be seen from these results that the success rate is almost 100% for those instances where at least 50% of the initial quantity of solid dissolves. For lower dissolution values, the error rate increases rapidly, suggesting that for the practical purposes of test design dissolution values of low intensity should be avoided. It is also clear that the arbitrary 50% success rate criterion for a detection threshold is not applicable in this instance since the detection rate is always better than 50%.

It may also be claimed, in passing, that pupils are unlikely to establish a sparingly soluble situation simply from this type of observation, but would need confirmation derived from suitable chemical tests. If the solubility of a lead salt was being investigated, for example, the solution could be shown to contain lead ions, not by observing the diminution in level of the solid, but by performing a sensitive chemical test for them on the super-natant liquid.

c) Results of threshold determinations in the colour perception area

The study of colour perception was restricted in this research to the detection of hue changes. These were brought about by adding to suitably coloured solutions containing Universal Indicator appropriate buffer solutions designed to bring about specific hue changes.

Although it is fairly difficult to quantify colour changes in a purely quantitative manner, nevertheless following the work of Cavanaugh and Schumacher (1966), the hue changes are listed in order of the approximate wavelength change, starting with the largest first (red to purple).

The results, which give the success rates expressed as percentages of the population succeeding in the detection of each hue change are shown in Table 6 and illustrated in Figure 6. (In the yellow to orange change, sodium chromate solution was used instead of Universal Indicator solution to achieve the desired effect).

Table 6

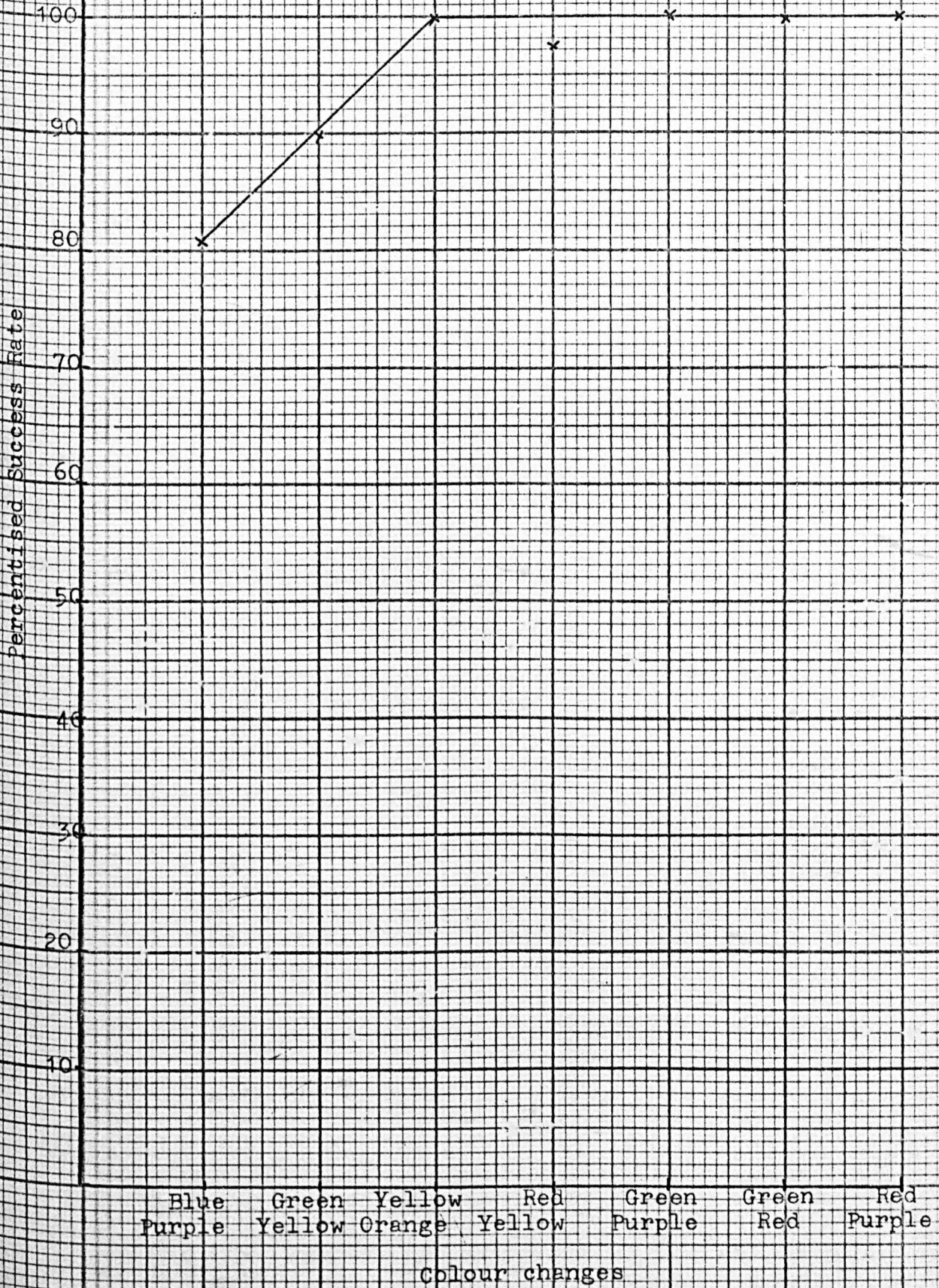
Success rates achieved in detecting hue changes shown as percentages

Hue change	Percentised success rate
Red to purple	100
Green to red	100
Green to purple	100
Red to yellow	97
Yellow to orange	100
Green to yellow	90
Blue to purple	81

Population = 89

Figure 6

Graph showing the percentised success rates obtained in detecting colour changes of varying hues



It can be seen from an examination of this data that the detection rate for colour changes is extremely high, all but two being at the 100% level or very close to it. Thus, from the point of view of a standardised test development, the high detection rate (81%) of even the most difficult colour change (blue to purple) makes it necessary to reconsider the adoption of the 50% detection level as the norm for use throughout the test.

Therefore it would seem that, in the light of the findings of this part of the study and also of the solubility detection experiments, a higher detection rate than 50% should be considered as an accepted threshold value if equivalence of stimulus detection is to be attained in the design of standardised observation tests.

d) Perception thresholds in systems involving gases

Only two aspects of this perceptual area are considered in this study; namely the detection of effervescence and the detection of odours.

i) Results of the study into effervescence thresholds

The changes were caused by the reactions between solutions of acid and of soluble carbonates. The intensity of the effervescence was measured in terms of the volume of gas produced by 1 cm³ of reacting solutions. The results of this part of the study are summarised in Table 7 and illustrated in Figure 7. The success rate data given in the table represents the extent to which the effervescences were correctly detected by the pupils.

Table 7

Results of the effervescence threshold study

Stimulus Intensity 'Volume' of gas evolved	Percentised success rate
11	100
5	100
2	99
0.5	85
0	84

Total volume of reactants = 8 cm³

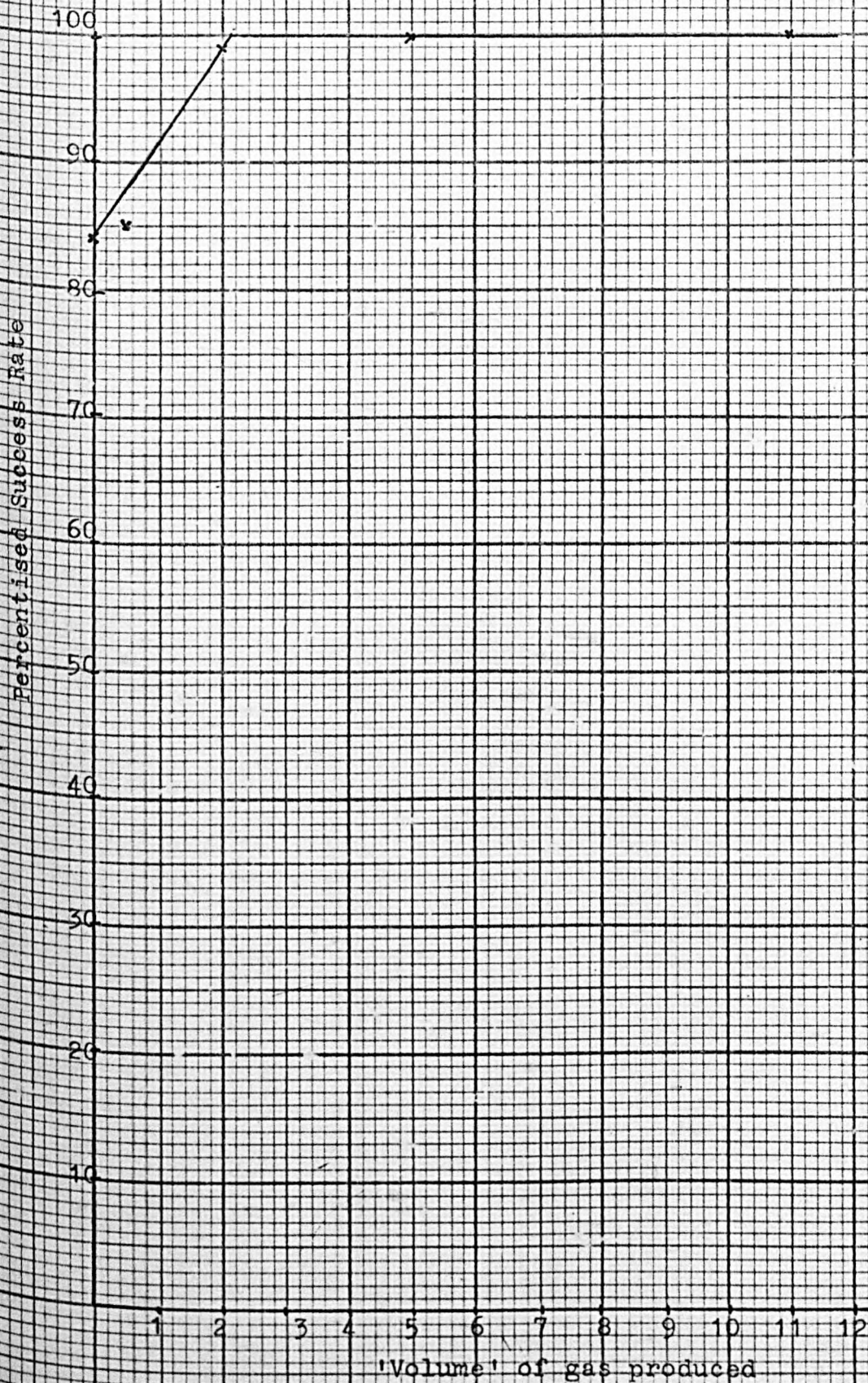
Number in population = 94

It can be seen from the data in Table 7 that there is very little uncertainty involved in the detection of this particular stimulus, whatever the intensity. It is possible to explain the 16% error rate associated with the 'no effervescence' reaction. The pupils were told to shake the tubes in order to achieve complete mixing of reagents. It is therefore possible that the pupils who reported an effervescence, when one was totally impossible, may have mistaken the escape of trapped air bubbles for the small bubbles typical of a genuine effervescence.

It can also be seen that the very high detection rate in this area reinforces the need to adopt a higher threshold value than the arbitrary 50% as an overall level in any standardised observation test.

Figure 7

Graph showing the percentised success rates
obtained in the detection of effervescences
of varying degrees of intensity



ii) Results of the study into thresholds associated with olfactory changes

The olfactory changes were brought about by progressively reducing the smell of ammonia emanating from the solution of ammonium hydroxide, by neutralising the ammonia with dilute acid. The response mode was Yes/No, but the method of presentation, although essentially 'Constant Stimulus', differed from that previously used in the study in that, instead of using a random presentation of stimuli either side of the expected threshold, it was found convenient to use a progressive reduction method.

The students recorded the volume of acid added at which they believed the odour had disappeared. The author calculated the molarity of ammonium hydroxide corresponding to this value which served as a form of stimulus intensity, and the results shown in Table 8 give the percentage of students who could detect the odour of ammonia at specified ammonium hydroxide concentrations.

Table 8

Percentised success rates for the detection of the smell of ammonia, emanating from solutions of ammonium hydroxide of varying concentrations

Stimulus intensity measured as molarity of ammonium hydroxide	Percentised success rate
1.9	100
1.7	100
1.5	96
1.3	88
1.1	77
0.9	74
0.7	73
0.5	67
0.3	59
0.1	49
0	85

Total population = 88

An examination of this data reveals two main results. First, pupils detected the smell of ammonia at the higher concentration values with some degree of ease, and they were almost equally certain when it was totally absent. Second, between these upper and lower limits there exists an area of diminished certainty. One suspects that at the very low levels detection becomes a matter of guesswork.

Therefore taking cognisance of these points, it would seem advisable to ensure that, in any form of standardised test, the smell of a gas should be as intense as possible, commensurate of course with safety considerations, and slight smells should therefore be avoided.

e) Threshold determinations in multi-stimuli situations

The study of multi-stimuli detection thresholds was limited in this part of the research to instances where the visual observation of an effervescence was combined with the haptic detection of a temperature rise.

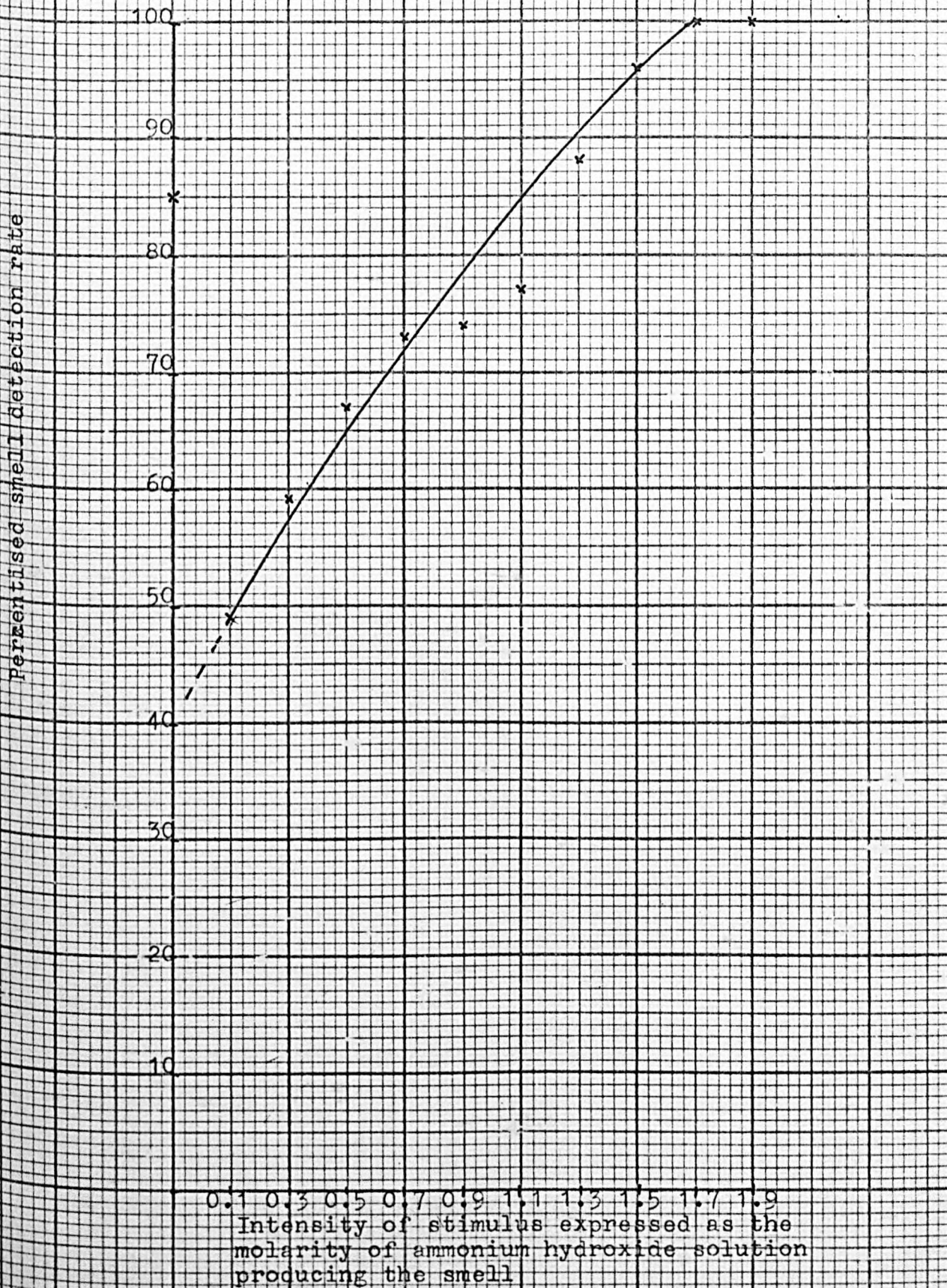
The effervescences were brought about by mixing solutions of acids and soluble carbonates, and at the same time the acid reacted with the strong alkali also present to give a temperature rise, detectable more or less simultaneously with the effervescence. This part of the work involved two sets of experiments. In the first the magnitude of the temperature change was kept constant whilst the magnitude of the effervescence was made the variable factor, and in the second experiment the roles were reversed.

i) Results of the variable effervescence/constant haptic experiment

The haptic thermal stimulus was presented at such a level that 100% detection would be expected in a single-stimulus change, whilst the stimulus intensities of

Figure 8

Graph showing how the percentised detection rate of the smell of ammonia gas varies with concentration of the emitting ammonium hydroxide solution



the effervescence, measured in terms of 'Volume' strength (as in section VI d i) of this chapter), closely mirrored those used in that section in order to facilitate comparison between the single-stimulus and multi-stimuli situations.

The results of this part of the investigation, together with a comparison with the results obtained in the single-stimulus effervescence determination follow in Table 9 and are illustrated graphically in Figure 9.

It should be noted that the population used was different from that in the earlier parts of the study in order to avoid the risk of aperception.

Table 9

Results of the study investigating the detection threshold for a variable effervescence in the presence of a constant thermal one, compared to a single-stimulus situation

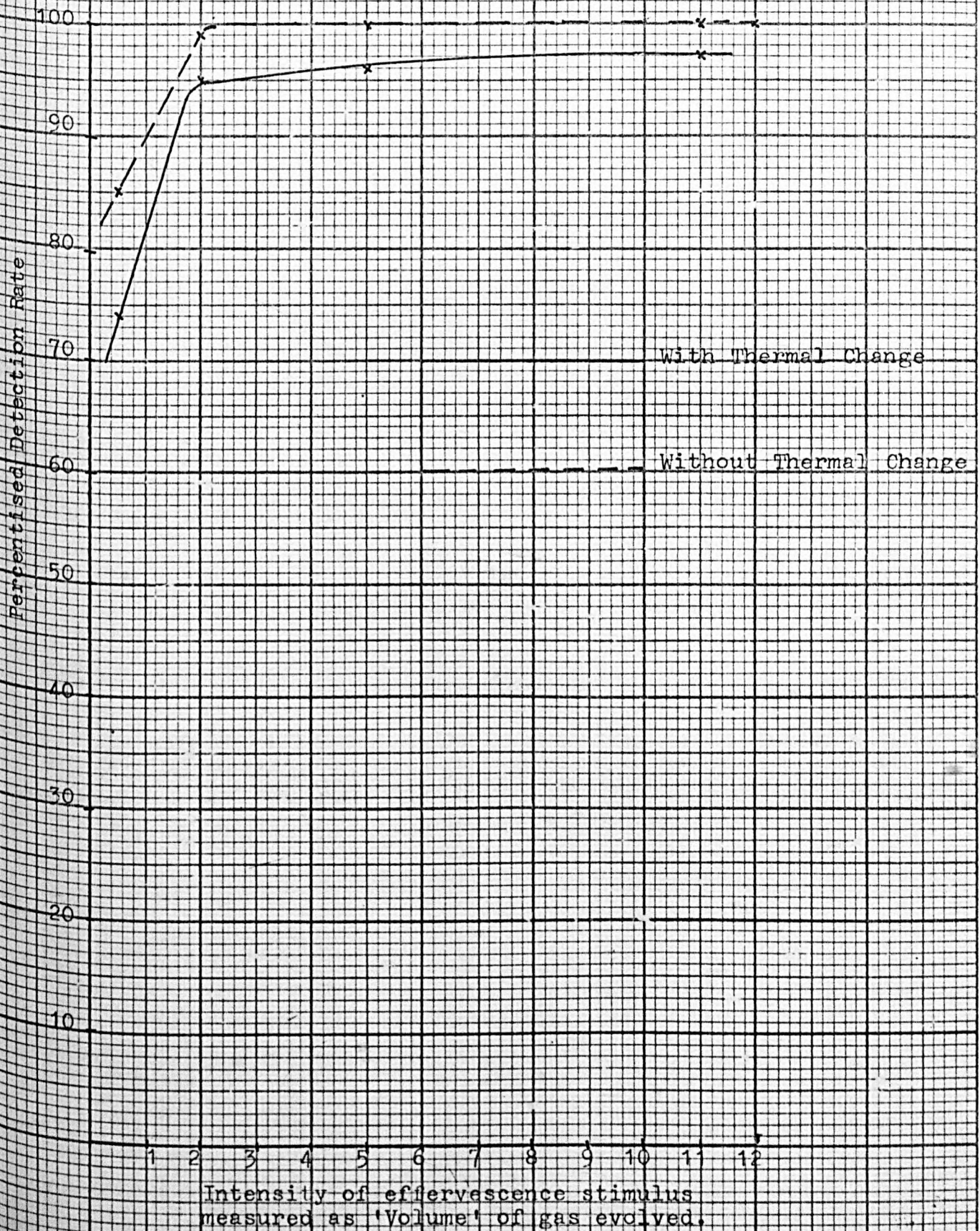
Stimulus intensities		Percentised detection rates		
Effervescence measured as 'Volume' of gas	Thermal °C	Thermal with efferv.	Effervescence with thermal	Effervescence alone
11	10	98	97	100
5	10	96	96	100
2	10	98	95	99
0.5	11	98	74	85
0	11	98	86	84

Total population = 89

Two points of interest emerge from an examination of this data. First, the detection rate of the thermal change has not changed significantly; it is detected with ease. Second, the presence of the thermal stimulus brought about

Figure 9

Comparison of detection thresholds relating to effervescence with and without a thermal stimulus background



lower detection rates with respect to the effervescence stimuli compared with those obtained in a single-stimulus situation.

To examine whether any significant difference existed between the detection rates of the effervescence stimulus with and without the addition of a thermal one, scores on this test were calculated by awarding one mark for each 'correct' identification of an effervescence, irrespective of magnitude. Mean scores and standard deviations were then calculated for both sets of instances. The results obtained are shown in Table 10.

Table 10

Mean scores and standard deviations obtained in detecting effervescences with and without the presence of a thermal stimulus

Situation	Mean score	Standard deviation	Population
With thermal stimulus	4.45	0.74	89
Without thermal stimulus	4.62	0.57	94

A t-test applied to this data gave a value of 1.73, which does not reach significance at the 0.05 level ($t = 1.96$ for 182 degrees of freedom). Therefore, although there is some deterioration in the detection of an effervescence when a thermal stimulus is also present, this is not significant. This is not surprising since reference to page 60 shows that effervescences are easy to detect. Thus pupils are not distracted significantly from detecting effervescences if a thermal stimulus is also present.

ii) Results of the constant effervescence/
variable haptic experiment

Here, as in the previous experiment, the 'constant' stimulus, in this instance effervescence, was presented at a level that would result in 100% detection in a single-stimulus presentation, and the temperature change was made the variable stimulus. The temperature range used was between 15°C and 0.5°C. The results of this investigation together with a comparison with the results from section VI a) (single haptic stimulus study) are displayed in Table 11 and illustrated graphically in Figure 10.

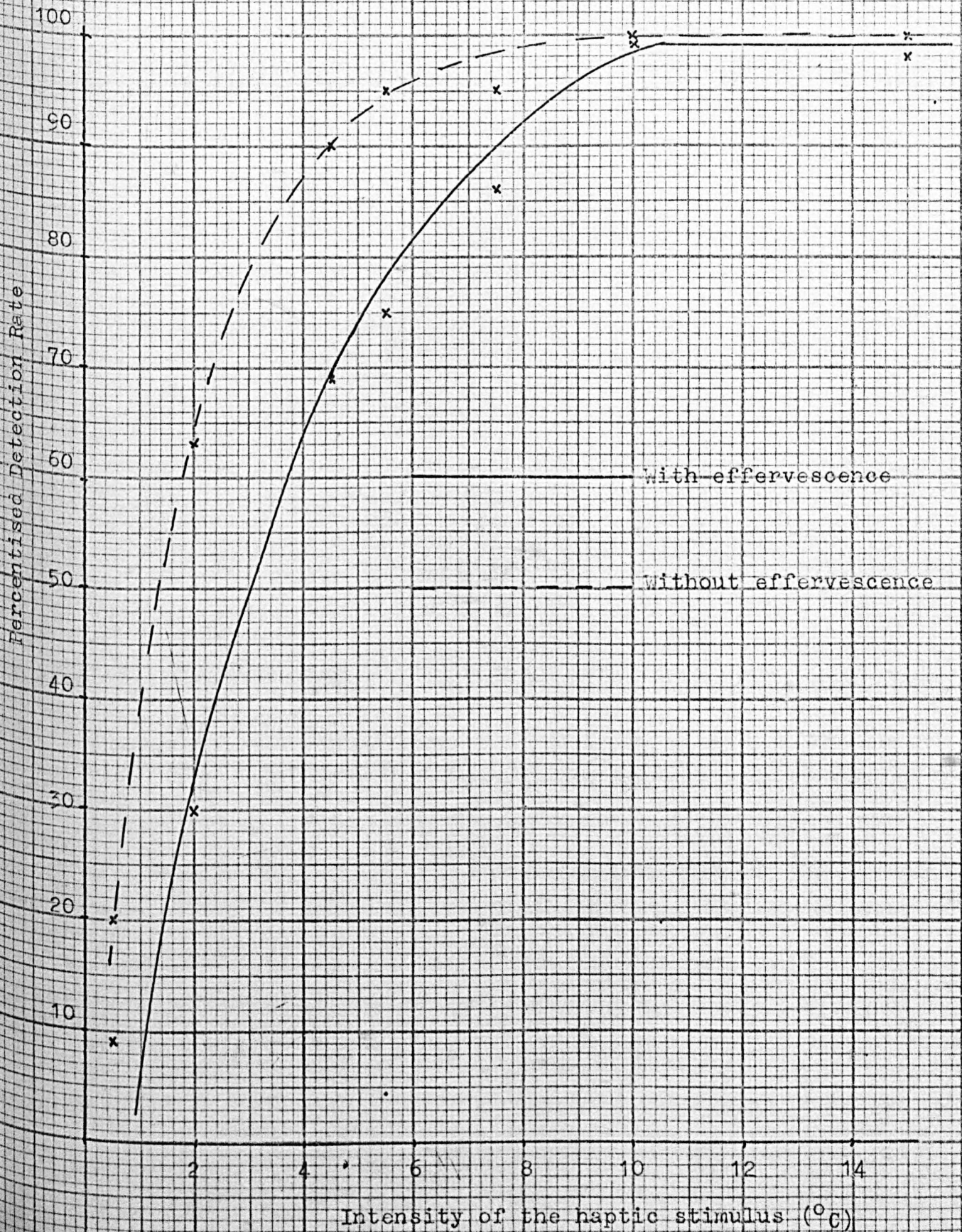
Table 11

Results of the study into the detection of a
variable thermal stimulus in the presence of
a constant effervescence, compared to a single-
stimulus situation

Stimulus intensities		Percentised detection rates		
Thermal °C	Effervescence measured as 'Volume' of gas	Thermal with efferv.	Thermal only	Effervescence with thermal
15	5	98	100	100
10	5	99	100	98
7.5	5	86	95	91
5.5	5	75	95	99
4.5	5	69	90	95
2.0	5	30	63	96
0.5	5	9	20	99

Figure 10

Comparison of relative detection thresholds
of a thermal change with and without constant
effervescence stimulus



Two main points emerge from an examination of these data. First, there is little change observed in the detection of the constant, effervescence, stimulus. Second, however, there seems to be a marked deterioration in the detection rate of the thermal stimulus below the point where the temperature change to be detected is 10°C. To examine if this difference in performance was a significant one, scores on the test were calculated, as in the previous experiment by awarding one mark for each correct temperature change identification below 10°C, irrespective of magnitude. Since there were five instances below, the maximum score was 5. Mean scores and standard deviations were then calculated for single-stimulus and multi-stimuli situations. The results are shown in Table 12.

Table 12

Mean scores and standard deviations obtained in the detection of thermal changes with and without the presence of an effervescence stimulus

Situation	Mean	Standard deviation	Population
With effervescence	2.70	1.04	78
Without effervescence	3.58	0.98	60

A t-test applied to these means showed that the difference was significant at the 0.01 level, $t = 5.71$ ($t = 2.576$ for significance at the 0.01 level with 137 degrees of freedom).

It would appear that in this particular combination of stimuli, pupils experience a significant division of attention when the effervescence stimulus is presented at a high level of intensity and the thermal stimuli are of low intensities; whereas, if both stimuli are of similar, high

intensity, then there is little interaction effect to be observed.

An examination of Figure 10 also shows that the effect of divided attention becomes more severe as the relative difference in intensities between constant and variable stimuli increases. Thus any degree of uncertainty on the part of an observer in terms of the ability to detect a 'difficult' stimulus, is exacerbated by requiring him to divide his attention between it and a more obvious stimulus.

VII Summary and conclusions

a) Summary

i) Throughout the section it is evident, and not surprising, that as the intensity of a stimulus is reduced so it becomes more difficult to detect.

ii) However, the extent of this increase in difficulty varied with the type of stimulus offered for detection. Basically two patterns emerged. In the first there was very little deterioration in detection rate as the stimulus intensity was reduced. This type is perhaps best exemplified by colour perception thresholds. In the second variant, the detection rate varied considerably with stimulus intensity. This type is exemplified by the haptic perception thresholds.

iii) This essential difference in the way that stimulus detection varies with stimulus intensity is also reflected in the interaction of one stimulus upon another in multi-stimuli situations. It will be remembered that in both parts of the multi-stimuli experiment there was a deterioration in the detection rate of the variable stimulus; but in a situation where the variable stimulus was of the

type that showed little detection variation in single-stimulus conditions, as the intensity of the stimulus was reduced; then the deterioration caused by the second stimulus was small and non-significant. In the situation, however, where the variable stimulus was of the type where its single-stimulus detection rate fell off rapidly as the stimulus intensity was lowered, e.g., a thermal change, then the deterioration was even more marked as a result of adding a second stimulus.

It would seem that the intrinsic uncertainty met in dealing with, for example, low-intensity haptic stimuli was further complicated by the fact that the other, more prominent stimulus brought about a significant and disparate division of attention, with the prominent stimulus claiming most of it.

b) Detection thresholds and their use in the design of a standardised observation test

One of the prime requirements for a standardised test of observation is that all stimuli presented for detection should be of equal difficulty, i.e., they should have similar facility indices. It would seem appropriate therefore, to present all stimuli at high levels of intensity for the following reasons.

i) If a low intensity level, i.e., the arbitrary 50% level, is chosen, then the test will be unbalanced in this aspect since some stimuli, e.g., those of effervescence and colour, are too easy to detect and are incapable of being reduced to that level.

ii) It has been shown in the work on multi-stimuli situations that if both stimuli are presented at a high

level of intensity, then there is very little risk of interaction between them, even if one of the stimuli is of the kind where detection rate falls off rapidly as stimulus intensity is reduced. It may therefore be assumed, with some confidence, that facility indices determined for single-stimulus changes still hold in multi-stimuli situations if the various intensities are kept high.

c) Applications to the design of other aspects of practical work in chemistry

In the introduction to the present chapter (page 28), it was pointed out that although the prime purpose of the threshold study was to establish detection thresholds which could be used subsequently to facilitate the design of a standardised observation test; a secondary purpose was to provide information of a quantitative nature which could be used in the design and assessment of practical work.

It is evident from the results that the tacit assumption made by many teachers that, if they know (from the specification of the reactants) that a particular observable phenomenon will happen in a chemical change then pupils without that prior knowledge will also make a successful observation, cannot always be justified. For example, it might have been thought that a precipitate would be detectable whatever its intensity, but section VI b) ii) shows quite clearly that precipitates, whose settled depth as defined in that section are equal to 0.5 mm, stood only a 25% chance of being discovered even in a situation where an observer is specifically looking for a precipitate. It is therefore probable that in practical chemistry observation situations of an open-ended type, where the pupil receives no such specific guidance as to what to look for, the detection possibilities could be even lower than 25%. Thus one ought to present stimuli at such levels of

intensity that their discovery will not be a matter of chance.

However, just as in the sphere of cognitive testing, test-items of graded difficulty can be presented to pupils to monitor their intellectual progress; so it should be possible, in an observational context, to design observational tasks varying in degree of difficulty. For instance, in the detection of the redissolution of a precipitate, the data on page 51 would indicate that if a 100% redissolution is reduced to only 70%, then only 70% of the pupils will be able to make the more difficult detection. Thus a series of observational tasks graded in order of difficulty could be constructed for use in teaching or examining situations.

CHAPTER 5 A STUDY INTO THE RELATIONSHIP BETWEEN
DIFFERENT MODES OF TASK DEFINITION AND
OBSERVATIONAL ATTAINMENT

I Introduction

This part of the thesis concerned itself with an investigation into the effects of different modes of task definition on pupils' observational attainment. The modes of task definition were chosen as follows:

- i) an open-ended approach, in which observational tasks had to be accomplished in the absence of any form of cueing;
- ii) a partial-direction approach, in which pupils received cueing to some, but not all, observations to be made;
- iii) a check-list approach, in which pupils were required to carry out observational tasks with reference to a comprehensive schedule listing all possible observations.

The areas of perception to be represented in the test were essentially those already referred to in the threshold study, i.e., (a) visual changes, subdivided into

- i) colour changes
 - ii) changes involving the appearance or disappearance of solids from solutions
 - iii) changes involving the formation of gases from solutions;
- b) haptic changes, which in this study were restricted to temperature rises obtained when reagents were mixed; and
- c) olfactory changes, which were in the form of the appearance or disappearance of smells.

Four basic requirements arose as regards the design and structure of the observational tasks:

- a) they should allow formulation in terms of the three modes of task definition chosen;
- b) they should reflect a reasonable balance between the perceptual areas given above;

- c) they should present combinations of observational tasks at varying degrees of task complexity, where this is expressed as the total number of possible observations associated with each reaction; and
- d) they should reflect in all instances an adequate level of stimulus intensity, i.e., a stimulus intensity well above arbitrary observational threshold limits.

As will be seen in the following section, requirements a) and d) were fully achieved. The balance between areas in the final test showed some deficiency as regards thermal changes, but this is merely a reflection of the relative incidence of this type of change in contemporary teaching situations. As far as the task complexity criterion was concerned, some difficulties were encountered in the design of the tasks, but this is a reflection of the range of chemical reactions suitable for school use and arising from simple mixing experiments.

To prevent the investigation from being affected unduly by the manipulative competency of the pupils involved, it was considered important to confine the range of observational phenomena to those arising from simple test-tube reactions, e.g., those initiated by mixing solutions or adding solutions to solids. Furthermore, the observations to be recognised and described had to be well within the capabilities of the pupils so that the cognitive demand upon them was minimised.

II The design of the standardised observation test

- a) Presentation of the test in terms of the three modes of task definition

The instructions to pupils covered two aspects:

- i) the manipulative requirements and
- ii) the observational requirements.

In all three modes the manipulative instructions were couched in exactly the same form, but the observational task was, of course, defined differently in each of the three modes.

In the open-ended mode pupils were required to write down all that they observed and thus received no cueing.

In the partial-direction mode the manipulative instructions were followed by a specific question, which supplied the restricted form of cueing referred to in the introduction. The pupils were also required to record all other observations that they made.

In the check-list approach, pupils were required:

- a) to tick off all observations they made on the check-list provided, which included all phenomena which could possibly be observed; and
- b) they were required to write an account of what they had observed, aided by the completed check-list. Each item in the test had its own check-list appended.

Thus it was fully possible to formulate the test instructions according to each mode of task definition.

b) The perceptual content of the test

This aspect of the design looked at two inter-related factors, namely the perceptual areas represented and the task complexities associated with the items chosen.

For administrative convenience the test was designed to fit into a normal school double-period of between 70 to 80 minutes, and it was felt that this would allow for about 12 different items to be included. The choice of reactions was, as was stated in section I of this chapter, limited to those which occurred as a result of simple mixing experiments, but 'familiar' reactions, i.e., those which might have been

met in classroom situations and remembered, were avoided so that aperception could be kept to a minimum. Of the 12 reactions chosen, one was eliminated in the subsequent assessment because of a faulty reagent bottle supplied to one of the schools.

Table 13 shows the perceptual content of the standardised observation test, together with the appropriate task-complexity values (the total number of observable stimuli to be detected in each item).

Table 13

The perceptual content of the practical test

Reaction identity	Perceptual areas				Task complexity
	Colour	Solids	Thermal	Gas	
1	1		1	1	3
2				1	1
3	1	2	1	1	5
4		2			2
5	2	1		1	4
6	1	1	1		3
7	2			1	3
8	1	2		1	4
9					0
10	1			1	2
(11)	(1)		(1)		(2)
12	2	1	1	3	7
Totals	11 (12)	9	4 (5)	10	34 (36)

(Reaction 11 data is included in parentheses for the sake of completeness, since it was part of the original design, and was in fact used subsequently in the larger scale

investigation which will be referred to on pages 115-120.

It has been pointed out earlier that the test showed some deficiency in the number of stimuli presented in the thermal area, and an inspection of Table 13 confirms this; but an examination of the Nuffield 'O'-Level Sample Scheme (1966), (in use at the schools participating in the tests), revealed that, in terms of the perceptual content of that course, there was a relatively low incidence of thermal stimuli included, with only 4 out of a possible total 122 observations being thermal in nature. Thus this tendency is reflected in a somewhat lower proportion of thermal stimuli in comparison with the others.

It will also be observed that the task-complexity value included ranged from 0 to 7 with task-complexity value 6 omitted. Efforts were made to design such a reaction, but it was not found to be possible. Even so, a reasonable spread of task-complexity values were used with 7 being the maximum possible in the circumstances.

c) Selection of stimuli for the partial-cueing aspects of the partial-direction mode

It will be remembered that in this mode cueing was provided for some, but not all, of the observable stimuli. It was decided to supply one specific cue, in the form of a question, for each of the twelve reactions originally included in the test, and to spread these as evenly as possible among the perceptual areas. This was accomplished by examining the different types of perceptual area and distributing the uses as shown in Table 14. (An example of the type of question used is as follows: "Are there any changes involving colour?").

Table 14

Distribution of partial-direction cues

Perceptual area	Number of cues
Colour	1 (2)
Solids	3
Thermal "	2
Effervescences	3
Smells	2

(Of the 12 cues, a colour cue was eliminated with the elimination of reaction 11).

d) The attainment of stimulus-equivalence in the test

In the conclusions to the work described in the threshold study on pages 72 and 73, it was recommended that the stimuli to be used in the observational test should be presented at a higher level of intensity than that required to satisfy the 50% detection level.

The reasons for this, it will be remembered, were basically as follows:

i) The very nature of some stimuli, i.e., colour changes meant that they were easy to detect anyway and thus were always detected at better than the 50% level.

ii) When two stimuli were presented together there was found to be little or no interaction between them if both stimuli were presented at high levels of intensity.

iii) At these high levels of intensity, even with those stimuli which seemed to be difficult to detect at lower intensity levels, there was a reproducibility in the detection rate when more than one example of the same

stimulus intensity was offered for detection; but at low intensity levels, in the detection of a thermal change, for example, there was a wide variation in detection rate when equivalent stimuli were presented.

Thus in the light of the points made above, the concentrations of the reagents used were adjusted, as far as possible, to give predicted detection rates of 85% or better. In practice it was not always possible to achieve this exactly, since in a multi-stimuli situation producing, for example, a heat change, an effervescence, a dissolution and a smell, the concentrations of acid needed to produce each of the stimuli separately at the 85% detection rate differed slightly, hence particularly in the more complex reactions, compromise concentrations had to be adopted. This however, did not lead to any serious discrepancies in this aspect of test design.

III Ancillary tests

In addition to the main, observational, test it was decided to include ancillary tests in the test battery for two distinct purposes. The first was to provide information about the population and its sampling, and the second was to investigate the relationship between observational attainment and other factors considered to be relevant to observation in chemistry.

a) Tests concerned with the population sampling

These tests were

- i) a colour vision test, and
- ii) the AH4 test of General Intelligence

i) The colour vision test

This was thought to be essential since, as

was shown in Section II of this chapter, 11 of the perceptual stimuli used in the amended version of the observational test were colour-oriented. Therefore if any of the pupils participating in the test had colour-vision deficiencies, then up to approximately one third of the stimuli would either be undetectable or offer severe detectional difficulties to the colour deficient pupils.

To enquire into this aspect, colour slides were prepared, each of which showed two bottles containing coloured solutions, and each bottle was given a letter code. Answer sheets were also prepared and pupils were required to describe the hue of each solution using only the hue names specified on the instruction/answer sheet. A copy of this is shown in Appendix B i).

ii) The AH4 test

This is basically a standardised test of general intelligence, and it was used simply to check that, in terms of this factor, the sub-populations allocated to the various treatment groups were similar. Thus any subsequent differences in observational attainment could not be explained by population variations of this nature.

b) Ancillary tests designed to investigate some factors likely to be relevant to observational attainment

Two tests were included here:

- i) a chemistry theory test, and
- ii) the hidden figures test.

i) The chemistry theory test

This was included in the test battery for the following reason. It is possible that a pupil with a good knowledge of the cognitive aspects of chemistry might be

better equipped in terms of knowing what to look for in an observational test than a pupil with a more imperfect background chemical knowledge. For example, a pupil who knew exactly what an effervescence was could have an advantage over another pupil whose cognitive knowledge of the term 'effervescence' was at fault. Also pupils with good cognitive background following the open-ended mode where no cueing was given, could have an advantage over pupils with a more restricted background in actually knowing what to look for.

Thus a chemistry test was constructed consisting of 30 multiple-choice items. With one exception, the items were identical with those in Ward's 1971 study. The test had a time limit, and the items used are displayed in Appendix B ii).

ii) The hidden figures test

The fact that certain individuals performed a given cognitive task in a different manner from that employed by others was referred to in Chapter 2 in the discussion on cognitive styles, and it was stated there that extensive research into these individual differences had led to the realisation that there are several dimensions of individual differences which have come to be accepted as cognitive styles.

Cognitive styles are concerned with the form, rather than the content, of cognitive activity. They refer to how we perceive or think or learn, not to what is perceived or thought or learned.

In terms specifically of perception, material referred to in Chapter 2 showed that subjects who could extract a simple figure from complex one quickly and easily and who

could position a rod vertically, irrespective of the distracting frame, were termed 'field-independent', i.e., those who could ignore background distractions, and those who could not do either were termed 'field-dependent', i.e., those who were strongly influenced by background considerations.

If one now considered the situation in practical chemistry where a pupil has to detect whether a particular stimulus is absent or present, it can be seen that we have a similar situation. The test-tube in which the change concerned takes place is also the place where many other things are happening. For example, in the reaction with task-complexity value 7, described in Table 13 on page 78, if a pupil is looking for a colour change, there are also five other changes competing for his attention, to say nothing of the general background in the laboratory. Thus one could speculate that a pupil whose particular cognitive style, in this respect, was of the field-independent type would be better equipped to perceive in a more organised way the various stimuli available for detection, than would a field-dependent person, whose attention would be almost entirely taken up by the complexities of the overall reaction.

It can also be hypothesised that this tendency of field-independent pupils to perceive better and thus return better observational scores than the field-dependent pupils, will be most marked in the form of task definition that gives the least amount of external guidance to the pupils, i.e., the open-ended form.

Thus it was decided to include a hidden figures test, developed at the University of Keele, in the test battery to find out if field-independent subjects could perceive more acutely various chemical stimuli in relatively complex situations.

The test was a 12 item test, with each simple figure having four complex ones in which it might, or might not, be present. Students had to record on the answer sheet definite presences or absences of the simple figure. The test and answer sheet are displayed in Appendix B iii). It is to be noted that this also was a timed test.

IV

Details of the population used and the administrative details of the tests

a) The population

This was drawn from pupils in their fourth year at two 11-18 comprehensive schools. All pupils were studying chemistry to either the 'O' or 'CSE' Level, and were in the second term of the fourth year.

Table 15 gives the details of the population.

Table 15

Populations used in the task-definition study

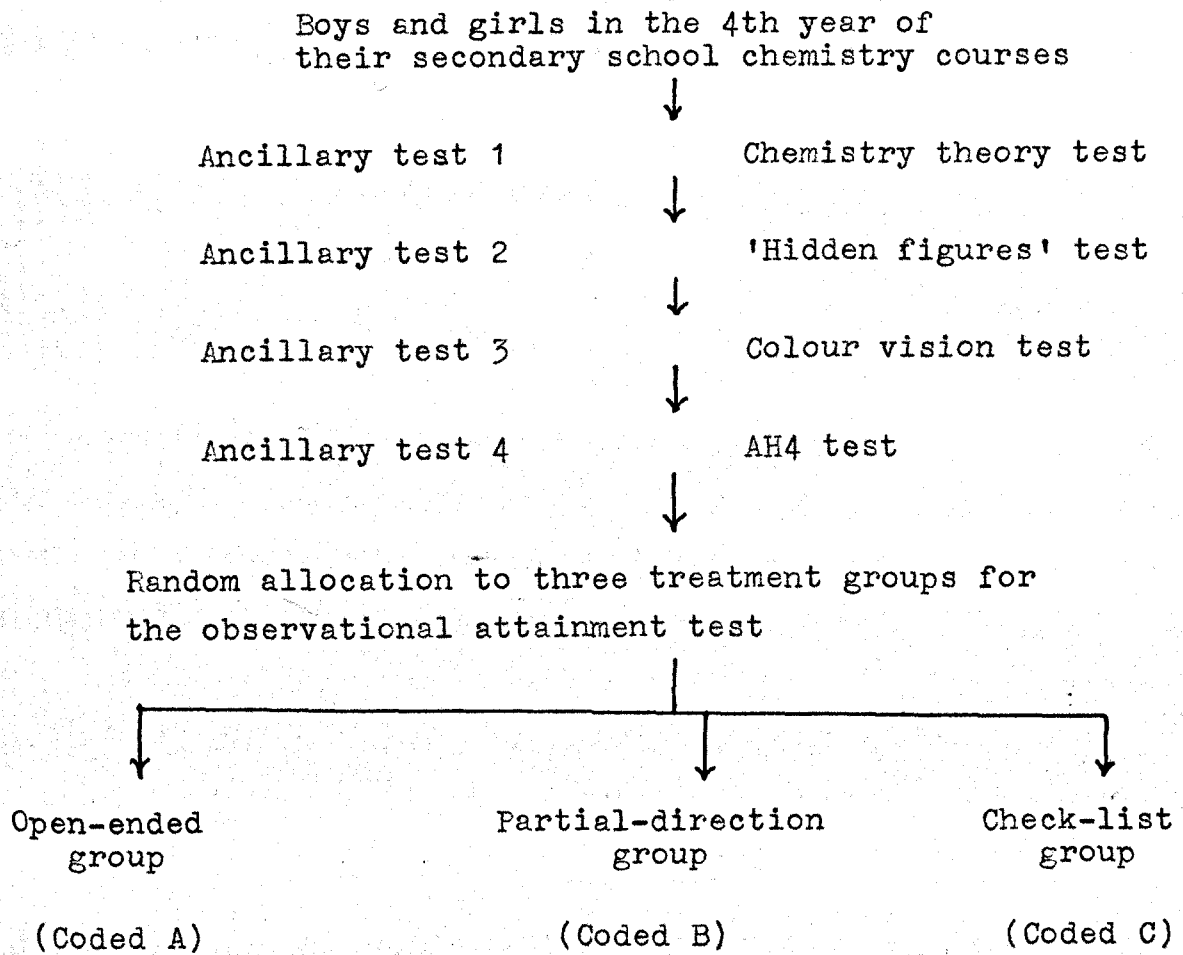
School	Number of boys	Number of girls
De Aston School, Market Rasen	55	34
Matthew Humberstone School, Cleethorpes	49	21
Total	104	55

The age range was between 14.0 and 15.0 years.

b) The overall administration of the tests

Figure 11 shows the overall strategy used.

Figure 11



i) The administration of the practical test

Before the practical test was undertaken all pupils were given an introductory talk by the author or a member of the appropriate school staff. The pupils had been allocated to one of the three treatment modes using the random number facility on a Texas SR.51A calculator.

Each student was given a combined instruction and reporting booklet appropriate to his or her practical mode. Copies of the booklets are displayed in Appendix B iv).

Pupils were supplied with sets of test-tubes marked at the 1" and 2" levels and had convenient access to the reagent bottles and solids necessary for the test. All chemicals were marked with code letters in order to prevent the test being one of aperception, i.e., deciding what was going to happen from a knowledge of the identity of the chemicals. (All reactions were simple in regard of their manipulative demands). The identity of the solutions and their concentrations is given in Appendix B v).

Throughout the test, examination conditions were maintained and there were sufficient sets of reagents (delivered from a bulked source) to keep movement about the laboratory to a minimum. No time limit was imposed and pupils had from 70-80 minutes to complete the test in class time, and more time was allowed where necessary.

ii) Administration of the ancillary tests

These were administered under examination conditions in the week before the practical test. In the case of the colour-vision test no time limit was imposed, but in the AH4, chemistry theory and hidden figures tests, the appropriate time limits laid down in the various rubrics

were adhered to. The results of the tests and a discussion follow in the next section of this chapter.

Results and discussion of the task-definition study

Introduction

As was indicated at the beginning of Section I of this chapter on page 75, this study required pupils to undertake a set of observational tasks in practical chemistry under different modes of task definition. The observational tasks themselves were constructed in the light of the work reported in the previous chapter, in that the concentrations of the reactants were so adjusted that the intensity of each stimulus presented for detection would ensure, in a single-stimulus situation, a detection rate of 85% or better. The test was a balanced one involving 34 stimuli from the four perceptual areas previously described also in Section I.

There were three treatment modes used in the study; the open-ended, the partial-direction and the check-list modes.

a) Results of the ancillary tests giving information about the population sampling.

These tests were

- i) a colour-vision test and
- ii) the AH4 test

i) The colour-vision test

As a result of this test, two pupils who could not satisfactorily identify all the colours presented to them were eliminated from the sample. This ensured that all those subsequently included in the sample had adequate colour vision.

ii) The AH4 test

The population, drawn from the two

comprehensive schools referred to earlier, had been allocated randomly to the three treatment groups. To examine the sub-populations for equivalence in terms of general intelligence, the AH4 test was administered.

The results of this test are displayed in Table 16 and a two-way analysis of variance performed on the AH4 data is shown in Table 17.

Table 16

Mean AH4 scores with respect to treatment groups and schools

Mean AH4 scores according to the assigned mode of task definition				
	Open-ended	Partial-direction	Check-list	
School I	$\bar{x} = 85.97$ S.D. = 15.84 n = 29	$\bar{x} = 83.22$ S.D. = 14.69 n = 31	$\bar{x} = 91.00$ S.D. = 11.69 n = 28	$\bar{x} = 86.60$ S.D.=14.14 n = 88
School II	$\bar{x} = 78.65$ S.D. = 15.00 n = 20	$\bar{x} = 84.68$ S.D. = 13.69 n = 19	$\bar{x} = 82.05$ S.D. = 13.95 n = 20	$\bar{x} = 81.74$ S.D.=14.20 n = 59
	$\bar{x} = 82.98$ S.D. = 15.50 n = 49	$\bar{x} = 83.78$ S.D. = 14.30 n = 50	$\bar{x} = 87.27$ S.D. = 12.63 n = 48	

\bar{x} = Mean
S.D. = Standard deviation
n - cell size

Total population
for this test = 147

(In Table 17 and all subsequent analysis of variance tables confidence level information was obtained by reference to data in Lindley & Miller (1952). The techniques used in analysis of variance calculations were those described in Lewis (1968)).

Table 17

Two-way analysis of the AH4 data shown
in Table 16

Source of variation	SS	df	MS	F	Significance level
School	832	1	832	3.66	N.S.
Assigned treatment mode	504	2	252	1.11	N.S.
Interaction	762	2	381	1.67	N.S.
Within cells	32079	141	227.5	--	--
Total	34176	146			

SS = Sum of squares

MS = Mean square

df = Degrees of freedom

It will be observed from the data shown in Tables 16 and 17 that there is no significant difference in general intelligence levels between the populations assigned to the three treatment groups, nor are there any such differences between the two school populations. Therefore, if there are any subsequent differences in observational attainment brought about by the modes of task definition, they cannot be ascribed to variations in general intelligence among the treatment groups.

b) The observational test

Overall comparison between the raw mean scores obtained on the standardised observational test with respect to treatment mode and school

i) The assessment of the test

Each stimulus correctly identified was given one mark, with the exception of the colour changes in reactions 5, 7 and 12. These were complex colour changes

and were given a mark value of two each if the complex nature was recognised. (This avoided the problem of intermediate hue categorisation; i.e., there are many changes in hue in going from yellow to blue, and to define exactly how many was difficult, hence the use of one mark for simple and two for complex colour changes). The results were assessed according to the reaction and the perceptual areas involved, and in all cases they were transcribed onto the marking grid shown in Appendix B vi), from the written accounts of the pupils.

ii) The results of the observational test

These are presented in Table 18 and this is followed in Table 19, by the results of a two-way analysis of variance carried out on the data in Table 18.

Table 18

Raw mean scores on the observational test
with respect to mode of task definition and school

Raw mean scores on the observation test according to mode				
	Open-ended	Partial-direction	Check-list	
School I	$\bar{x} = 25.34$ S.D. = 3.73 n = 29	$\bar{x} = 25.67$ S.D. = 2.85 n = 31	$\bar{x} = 26.62$ S.D. = 2.53 n = 29	$\bar{x} = 25.67$ S.D.=3.22 n = 89
School II	$\bar{x} = 23.60$ S.D. = 4.29 n = 20	$\bar{x} = 24.45$ S.D. = 2.39 n = 20	$\bar{x} = 26.59$ S.D. = 3.26 n = 22	$\bar{x} = 24.93$ S.D.=3.73 n = 62
	$\bar{x} = 24.63$ S.D. = 4.15 n = 49	$\bar{x} = 25.20$ S.D. = 2.71 n = 51	$\bar{x} = 26.61$ S.D. = 2.91 n = 51	

\bar{x} = Mean

Maximum Score = 34

S.D. = Standard deviation

Total population

n = Cell size

for the test = 151

Table 19

Results of the two-way Analysis of variance
performed on the data in Table 18

Source of variation	SS	df	MS	F	Significance level
Mode of task definition	103	2	51.5	4.73	> 0.01 level
School	32	1	32	2.96	N.S.
Interaction	23	2	11.5	1.67	N.S.
Within cells	1578	145	10.8		
Total	1736	150			

p (0.01 level and 2/145) = 4.61

p (0.01 level and 1/145) = 6.63

It can be seen from the data contained in Tables 18 and 19 that the mode of task definition followed does have a significant effect upon observational attainment, but it can also be seen that the schools from which the populations were drawn have not significantly affected observational performance; neither is there any significant interaction between the schools and the modes of task definition.

Therefore, in the light of these findings, in the results and discussion which follow, no further reference will be made to the different schools used in the study.

Inspection of the mean scores in Table 18 reveals that the observational attainment of pupils following the check-list mode is superior to that of pupils following either the open-ended or partial-direction mode. A separate analysis, in fact, showed that the difference between the mean scores of the populations following either the open-ended or partial-direction mode is not significant. This was shown by the fact that when a t-test of significance was applied to the relevant means and standard deviations, a value of $t = 0.81$ was obtained. For the difference in mean scores to be significant at the 0.01 level, it would have had to be at least 2.64 for 99 degrees of freedom, and it clearly fails to reach this value.

Therefore two main points emerge from these results. The first, of a direct nature, is the superiority of the check-list mode, and the second concerns the relative similarity of the other two modes in terms of the levels of observational attainment they produce.

iii) The superiority of the check-list mode

This mode, which produced superior levels of observational attainment in comparison to either of the other

two, appears to do so for straight forward reasons. The check-list provided (displayed in the pro-formas shown in Appendix B iv).) not only enables pupils to have a comprehensive set of cues which may motivate them into looking for stimuli, but it also enables them to check what they have observed against a list of all possible observations. Therefore the chance of certain observations being either overlooked or forgotten is clearly minimised. However, as will be shown in more detail in part d) of this section, the check-list mode also has the effect of inducing illusory observations (i.e., observations which can have no possible factual foundation) to a level which is higher than that observed for the other two modes. This in itself may offer a part explanation for the superiority of the check-list mode, in that the pupils were prepared to make all observations they possibly could, even if some turned out to be illusory.

iv) The relative equivalence of the observational attainment levels produced by the open-ended and partial-direction modes

As was indicated earlier in Section I of this chapter, pupils following the open-ended mode received no guidance, and pupils following the partial-direction mode received cueing to some, but not all, observations.

In Ward's (1971) study it was discovered that some 'blinking' occurred in the non-cued areas, i.e., pupils were so concerned with looking for the cued observations that their attention was kept from the rest, and thus observations were missed. In the same study it was found that the open-ended mode produced a higher level of observation attainment than the partial-direction mode, but in the present study this is clearly not the case. This difference

in the relative effects of the two modes may be the result of inadequate experimental design used in the 1971 study, where in the partial-direction mode, the limited cueing used there pointed the observers to observations which, in the light of the findings of the threshold study, proved insensitive to cueing because of their intrinsically obvious nature.

In order to examine this further, an analysis was made of the relative success rates of pupils following the partial-direction mode, in those areas which received cueing and those which did not. The data is presented in Table 20, which gives raw scores and maxima. Because the maxima are different in the cued and non-cued areas, percentised scores are also given for purposes of direct comparison.

Table 20

Relative performance of the partial-direction mode pupils in the cued and non-cued areas of the test

Area	Raw mean score	Maxima	Percentised score
Cued	9.51	11	86.4%
Non-cued	15.64	23	68.0%

(The overall success rate for pupils following this mode was 74.0% compared with 72.6% overall for the open-ended mode pupils).

It is clear that a distinction must be made between the detection of those observations to which cueing was provided and of those to which it was not. Thus, one needs to examine the performance of pupils in the open-ended mode in those areas where the partial-direction mode pupils received cueing and in those where they did not, if one is to make viable comparisons. This prompted a re-examination of the 1971

data (which were still in the author's possession) along similar lines.

Thus the partial-direction mode data, in both the present and 1971 studies, was analysed with respect to those observations for which cueing was provided and for those for which it was not. In addition the open-ended data was analysed in a similar way; i.e., the total score was broken down into those areas which corresponded to a) the cued areas of the part-direction mode and b) the non-cued areas. The results of these analyses are displayed in Table 21.

Table 21

Results of the analysis of the observational attainment of pupils following the partial-direction and open-ended modes in those areas deemed 'cued' and 'non-cued' with respect to the partial-direction mode

(Data for the present study and for the re-examination of ward's 1971 work are given).

Area	Percentised observational attainment		
	Partial-direction score (PD)	Comparative open-ended score (OE)	Difference (PD - OE)
Cued 1971 present	69.4	61.7	+ 7.7
	86.4	62.8	+ 23.6
Non-cued 1971 present	33.9	53.2	- 19.3
	68.0	77.3	- 9.3

It can be seen from this data that in both studies the scores on those parts of the test in the partial-direction mode which received cueing are enhanced when compared with the performance of the open-ended pupils on the identical items; whereas in those parts which are non-cued the scores obtained by the pupils following the partial-direction mode

were lower than those obtained by open-ended mode pupils on the same items.

The magnitude of these enhancements and depressions must, however, be related to the characteristics of the test used. The test used in the 1971 study was completely different from that used in the present one; thus no direct comparability can be assumed and no deeper meaning can be attached to the relative magnitudes involved. What can be said, however, is that the relative magnitudes determine the effectiveness of the open-ended and the partial-direction modes, and whereas pupils following the latter mode certainly did better in those areas which received the limited cueing, this had the effect of reducing the effectiveness of their observation of the other, non-cued, stimuli, thus giving rise to the partial 'blinkering' effect.

c) Analysis of observational performances in the different perceptual areas

Four distinct perceptual areas were covered in the test, namely, colour perception, perception of changes involving the appearance or disappearance of solids from solutions, the perception of thermal changes and the perception of gaseous changes.

Table 22 shows how the pupils following each of the modes of task definition performed in relation to the different perceptual areas. Since the different areas have different maxima, the data is presented in percentised form for ease of comparison.

Table 22

Percentised mean scores with respect to mode
of task definition and perceptual area

Perceptual Area	Percentised scores with respect to mode of task definition		
	Open-ended	Partial-direction	Check-list
Colour	$\bar{x} = 88.8$ S.D. = 10.5	$\bar{x} = 82.6$ S.D. = 11.2	$\bar{x} = 88.7$ S.D. = 7.9
Solids	$\bar{x} = 58.9$ S.D. = 21.2	$\bar{x} = 60.2$ S.D. = 21.5	$\bar{x} = 68.6$ S.D. = 21.4
Thermal	$\bar{x} = 75.0$ S.D. = 29.8	$\bar{x} = 78.3$ S.D. = 25.3	$\bar{x} = 85.5$ S.D. = 21.3
Gaseous	$\bar{x} = 65.6$ S.D. = 18.2	$\bar{x} = 75.3$ S.D. = 11.7	$\bar{x} = 72.0$ S.D. = 14.6
Total	$\bar{x} = 72.4$ S.D. = 12.2	$\bar{x} = 74.1$ S.D. = 7.9	$\bar{x} = 78.3$ S.D. = 8.6
	n = 49	n = 51	n = 51

\bar{x} = Mean S.D. = Standard deviation

(It must be noted that in this table the results of the partial-direction mode attainment are given as a combined total effect combining cued and non-cued observations).

An examination of the data shows that although there are variations in attainment level among the four perceptual areas, the overall picture leads to an achievement level being observed in the region of between 60 to 80%. In other words, the attainment level is all within one and the same band. This indicates that, almost irrespective of the mode of task definition, the design of the test tasks has been such that they are all of comparatively the same order of difficulty. Perhaps the solids area attainment was found to be at the lower end of the attainment band, but this does not distort the overall claim that the test is one of

balanced difficulty.

Analysis of the data

Although one cannot analyse the partial-direction data in detail since it is a combined result of cued and non-cued observations, one can look at the relative differences between the open-ended and check-list modes performances in some detail.

Efficiency of cueing in the different perceptual areas

It will be noted from Table 22 that although the cueing provided by the check-list does, in the total picture, bring about a significant difference between the attainment levels of the open-ended and check-list modes (as described in sub-section ii) page 92), nevertheless an examination of the scores on the four perceptual areas reveals that this enhancement is not a constant one, but varies quite markedly in efficiency among the four areas.

The enhancing effect of the check-list mode is most marked in the thermal and solids areas. The gaseous area shows less difference, but the remarkable feature is that this form of extensive cueing has practically no effect on the perception of colour changes when we compare the check-list and open-ended mode performances.

It would therefore appear that, in the case of the particular colour changes presented for detection to this particular population, the comparative ease of detection would suggest a dominance of this particular type of stimulus. This is also revealed by the fact that, whilst in the other perceptual areas cueing enhanced the performance of the check-list mode pupils in comparison with open-ended mode pupils, in colour detection no such enhancement took place

simply because the stimulus was so obvious that the cueing provided was, in fact, superfluous.

d) Errors made in the course of the observational test

In a previous study, Kempa and Ward (1975) drew attention to the existence of two different types of error that could be made in the observation process, namely errors of omission and errors of an illusory nature.

Errors of omission are those which occur when clearly observable phenomena remain undetected by the pupil; whereas errors of the illusory type occur when pupils report observations as having been made when, in reality, no such observations could possibly have been made in the circumstances.

These error rates are now examined in relation to the different modes of task definition under which the observational tasks had to be accomplished.

i) Omission errors

Intrinsically these do not, in fact, give us any new information since they are obtained by subtracting the scores of the pupils on the observation test from the maximum value possible. These values, expressed as percentages, are shown in Table 23.

Table 23

Omission error scores, expressed as percentages, considered in relation to treatment modes

Percentised omission error scores, by mode		
Open-ended	Partial-direction	Check-list
27.6%	25.9%	21.7%

Although this is not new information, in that it has been calculated from the data in Table 18, page 92, it does draw one's attention to the fact that even with the lowest

error rate, that obtained in the check-list mode, pupils are still failing to detect approximately one in five of the available stimuli. Thus it would seem that the magnitude of this error rate indicates that some form of teaching in observation is necessary to bring observation of stimuli up to a level where significantly fewer observations are missed if the subsequent interpretative stage, which depends on observational data, is not to suffer because of missing information.

ii) Illusory errors

Whereas omission errors have a direct arithmetical relationship to positive scores, there is no a priori reason why illusory errors should be so related, and thus, the main interest, in terms of errors, is in the field of illusory errors. The number of illusory errors made by each student was assessed, and Table 24 presents the mean number of such errors made by pupils in each of the three treatment modes.

Table 24
Mean illusory error scores considered in relation to mode of task definition

Mean number of illusory errors according to treatment mode		
Open-ended	Partial-direction	Check-list
$\bar{x} = 3.59$	$\bar{x} = 3.02$	$\bar{x} = 7.02$
S.D. = 2.65	S.D. = 1.73	S.D. = 4.62
n = 49	n = 51	n = 51

\bar{x} = Mean

S.D. = Standard deviation

n = Population size

From the data in Table 24, it can be seen that both the open-ended and partial-direction modes produce fewer illusory errors than does the check-list mode. It will be remembered, however, that the partial-direction mode involved a mixture of cued and non-cued observations; therefore without further analysis it is not possible to draw detailed conclusions from the overall partial-direction figures, but when a t-test was applied to the open-ended and check-list means and standard deviations it was found that the difference between them was a significant one. ($t = 4.48$ at 99 degrees of freedom giving significance at the 0.01 level of confidence).

A likely explanation for the higher number of errors induced by the use of the check-list is that it produces a situation where certain observations are 'suggested' to the pupil, and thus his imagination is triggered, and he is inclined to make 'observations' which have no foundation in terms of stimuli presented. (As a safe-guard, the author checked all illusory reportings). In the open-ended mode, however, no cueing was given and therefore the element of suggestibility was totally removed, but it is worth noting that even without this external form of suggestion, illusory errors were still made by the open-ended mode pupils. A more detailed analysis of illusory errors in terms of the four perceptual areas involved in the test follows in the next section.

iii) Illusory errors in the four perceptual areas

It will be remembered that actual observational stimuli were provided in the four perceptual areas relating to colour perception, solids perception, thermal perception and gaseous perception. To examine the

incidence of illusory errors in each of these areas the mean number of errors of this type made in each of the perceptual areas was calculated, and the data follows in Table 25.

Table 25

Mean number of illusory errors according to perceptual area and mode of task definition

Perceptual area	Mean number of illusory errors according to mode			Total Illusory error
	Open-ended	Partial-direction	Checklist	
Colour	0.33	0.26	0.54	1.13
Solid	0.24	0.35	1.13	1.72
Thermal	0.49	0.94	1.90	3.33
Gaseous	2.53	1.47	3.45	7.45
Total	3.59	3.02	7.02	—

An examination of the data given in Table 25 shows that not only is the number of illusory errors dependent on the mode of task definition used, it is also related to the perceptual areas involved. It would seem that the gaseous area is most prone to errors of an illusory type, with the thermal areas producing a smaller number (in the order of 50% fewer), and the colour and solids areas being far less prone to errors of this type.

It would seem reasonable to direct our attention to the gaseous and haptic areas because of the relatively high incidence of illusory errors in those fields.

Illusory errors in gaseous perception

In this field the type of reactions chosen for inclusion in the test brought about effervescence and changes in smell. To detect the former the visual sense is used and to detect

the latter the olfactory sense operates. In the threshold study, reported in Chapter 4, it was found in Section VI d i) that effervescences were comparatively easy to detect using the visual sense, and it may be suspected that illusory effervescences are reported when students mistake the release of trapped air bubbles, caused by vigorous shaking, for genuine effervescences.

Smells, however, are much more difficult to quantify, and it may be that very difficulty which renders the illusory reporting of smells a distinct possibility.

To enquire into the contribution that olfactory or visual illusory errors made to the gaseous illusory error total, the results were further analysed into gaseous illusions of a visual type and gaseous illusions depending on olfactory errors. Table 26 gives the results of this analysis.

Table 26

Mean number of gaseous illusory errors expressed as visual and olfactory components

	Mean illusory errors according to mode of task definition		
	Open-ended	Partial-direction	Check-list
Visual component	0.43	0.25	0.90
Olfactory component	2.10	1.22	2.55
Totals	2.53	1.47	3.45

An inspection of Table 26 clearly shows that it is the olfactory sense which is mainly responsible for gaseous illusory errors. One can appreciate that taking into account the ephemeral nature of smells, a pupil's imagination can readily be triggered so that he believes a smell of some

sort has been produced. In addition, whereas all other changes take place within the bounds of a test-tube; for a gas to be detected by its smell, it must escape from the tube and reach the pupil's nostrils and hence his chemoreceptors. It is conceivable that the gas can also be detected by a pupil some distance away, and if this detection happens to coincide with one of the second pupil's own reactions it may be quite wrongly associated with it.

Illusory errors in haptic perception

Thermal changes are, of course, detected by the sense of touch, and one can put forward a reasonable explanation for the comparatively high incidence of illusory errors in this area if one accepts that the clear and unambiguous recognition of temperature changes by touch alone is quite difficult and is prone to suggestion. This is borne out by a comparison of the figure of 0.49 errors made by pupils following the open-ended mode (where no cueing was given) with the 1.90 errors, almost four times as many, made by the check-list mode pupils with extensive cueing which included a thermally directed cue.

Finally, it should be noted that those observations which depend only on the visual sense for their detection, e.g., colour and solid changes, are least prone to illusory error.

e) Errors and their relationship to task complexity

In Section I of this chapter (page 75) the task complexity of a reaction was defined as the total number of possible observations associated with that reaction, and since it was shown in Section V c) (page 97) that the attainment levels in the different perceptual tasks in the

four perceptual areas were all within one and the same band, then we can accept the arithmetical sum of the number of observations to be made in a particular reaction as a valid task-complexity value.

We shall now consider the relationship between the task-complexity value and the frequency of errors both of the omission and illusory types.

i) Errors of omission and task-complexity values

The mean number of omission errors made in each of the experiments was calculated and then grouped data was derived, putting all reactions with identical task-complexity values together. The results, according to mode of task definition, are presented in Table 27.

Table 27

Mean number of omission errors made with respect to task-complexity value and mode of task definition

Task-complexity value (number of tasks in a particular test item)	Number of items in the test	Mean number of omission errors with respect to mode of task definition		
		Open-ended	Partial-direction	Check-list
1	1	0.06	0.10	0.16
2	2	0.31	0.44	0.30
3	2	0.51	0.49	0.48
4	3	1.50	1.13	1.24
5	1	1.82	1.74	1.25
7	1	2.54	2.49	1.54

An examination of this data leads us to two points of interest. The first concerns the fact that as the task-complexity value increases so does the number of omission errors made, irrespective of mode of task definition. The

second point, however, concerns the differential effect that particularly the check-list and open-ended modes have on the numbers of omission errors made.

Concerning the first point, i.e. the rise in omission error rate with increase in task complexity, it appears that as the number of different observational tasks to be performed rises, so the ability of pupils to deal with each of the stimuli involved in a successful manner decreases. A further point presents itself, which is that the number of errors made does not increase smoothly as the task-complexity value rises from 1 to 7, instead it shows a rather sudden jump after task-complexity value 3. This tendency is noted in all three modes of task definition. It would appear that these particular pupils can cope with the task of observing three different stimuli more or less simultaneously; when four are presented, then problems are created which are not overcome so successfully.

A possible explanation for the "jump" in error rates when going from the perception of three stimuli to that of four, may be found in the assertion that perception is limited less by the intake of information by the perceptual systems than by the necessity of storing it in the memory for a finite period of time before recording can be carried out. This is in accord with the findings of Lawrence and Laberge referred to earlier in the thesis (Page 21).

In the present part of this study, the acts of observation were concentrated in short periods of time and the immediate memorisation of observed stimuli was therefore an essential precursor to the successful recording of the information. Hunter (1964) when reviewing the classical studies on "immediate" memory, pointed out that this has limited capacity. For instance, when a pupil in his mid-teens (the age group used for the study) is required to remember a group of spoken randomly ordered digits, he can,

on the average, cope with a group containing 7 such numbers. In terms of the retention of observed perceptual stimuli however, it would seem from the data shown in Table 27 that the "immediate" memory can only hold up to three unrelated stimuli. (An examination of Table 13, page 78, shows that the stimuli concerned in the reaction with task complexity values 3 and 4 are unrelated, and therefore require to be memorised as separate and unrelated items). When four perceptual stimuli are presented, the error rate increases significantly. This finding is in accord with that of Howland and Wiener (1963) and Wiener (1964) who, in experiments on the reading of a number of volt meters found that whereas the subjects succeeded in reading up to three volt meters accurately, errors were made when a fourth one was added.

It might, however, be thought that as the task complexity value continues to rise beyond 4, the error rate could continue to "jump" because of the increasingly difficult memory task, but an examination of Table 27 shows clearly that this is not so. This may be explained by the fact that as the reactions become more complex, it becomes increasingly difficult to present a series of unrelated stimuli. Thus a pupil is able to use his experience to connect one stimulus with others, enabling him to "group" observations in the memory. For instance, in reaction 12 (referred to on page 78) the changes were all derived from one reaction, and a pupil could use his experience to connect the dissolving of a piece of metal with an effervescence and the production of a smell. Therefore instead of having to store 7 separate items in the memory, the task is reduced to a "four" item task, with one of the items being a multiple one.

The second main point concerns itself with the differential effect brought out by the modes of task definition. As in previous analyses we accept that the partial-direction mode is a mixture of cued and non-cued observations and is therefore not

capable of being treated as a single entity, but we can make viable comparisons between stimuli detected on one hand using the open-ended mode, and on the other using the check-list mode, since we are dealing at each level of task complexity with an identical set of stimuli irrespective of mode.

It can be seen from Table 27 that the superiority of the check-list mode reported in Section V b) is most marked at the higher levels of task complexity. For instance, when the performance of the pupils following the open-ended and check-list modes is compared on the item with task-complexity value 1, the check-list mode offers no advantage whatsoever. This is also true for task-complexity values of 2 and 3. However, as we noted above, pupils start making far more omission errors when the task-complexity value is 4 or more, and it is here where the check-list mode reduces the number of errors made as compared with the open-ended mode.

For example, at a task-complexity value of 4, the advantage is something like 0.25 of an error, and at the highest value of task-complexity, i.e. 7, there is a 1.0 error difference between the two modes with the check-list mode being the superior mode.

Thus, it would seem that the number of omission errors increases as the task-complexity value increases, but the error rate becomes more accentuated when the task-complexity value = 4. It is also at this value, at which division of attention becomes a serious problem, that the function of the check-list mode in providing both a reminder of what the student is looking for and a quick and efficient method of checking off what has been detected really comes into its own.

ii) Illusory errors and their relation to task complexity

In the section dealing with illusory errors (Section V d) (ii, page 101), it was pointed out that the number of these errors made in any of the three modes of task definition varied with

the perceptual field, and it was thought reasonable to suppose that no direct relationship existed between the number of illusory errors made and the number of positive observations.

Thus a further aspect worthy of exploration is the relationship between the complexity of an observational task (measured by the number of positive observations possible in the given reaction) and the number of illusory errors made by students. For this, a procedure was adopted which was similar to that used for the study of the relationship between omission errors and task-complexity. The data are presented in Table 28.

Table 28 Mean numbers of illusory errors made with respect to task-complexity value and mode of task definition

Task-complexity value (number of tasks in a particular test item)	Number of items in the test	Mean number of illusory errors with respect to mode of task definition		
		Open-ended	Partial-direction	Check-list
0	1	0.10	0.65	0.51
1	1	0.24	0.12	0.71
2	2	0.50	0.20	0.72
3	3	0.44	0.39	0.93
4	2	0.23	0.22	0.39
5	1	0.48	0.27	0.59
7	1	0.02	0.06	0.08

The following three points of interest arise when the data is examined.

First, there is no particular trend relating the mean number of illusory errors to task-complexity value in any of the three modes. The values appear fairly randomised within each column. This is in contrast with the omission error/task-complexity value analysis, where reactions with high task-complexity values led to higher numbers of omission errors. This is demonstrably not true here.

The second point arises from the very low incidence of

illusory errors made across all modes in the reaction having task-complexity value 7. This reaction produced stimuli in all four perceptual areas including the illusory error prone haptic and olfactory regions. Thus when these are presented as 'real' observations there is little scope for illusion. Thus it would appear that the check-list mode is at its most useful when used with reactions of high task-complexity value. Not only does it produce significantly fewer omission errors, but it does not have the disadvantage of generating excessive illusory errors.

The third point of interest concerns the relatively high number of illusory errors made by partial-direction mode pupils on the reaction with task-complexity value 0. In Section V d) ii), it was pointed out that the check-list mode was most prone to illusory errors, but in this particular instance this is not true, since the partial-direction mode error rate exceeds that of either of the other two modes.

In the sets of instructions given to pupils following the partial-direction mode each reaction had a specific cue in the form of a question, and this was followed by a general instruction to report all other observations. In reaction 9 pupils actually added water to water and thus no change of any sort took place and therefore the task-complexity value was 0. To maintain the partial-direction format, a question was asked, but whereas in all the other reactions the cues pointed to positive responses, for example, in reaction 1, the cue to report on temperature changes drew pupils' attention to the temperature change that did take place; a similar cue in reaction 9, i.e. a thermal one, should have had the response 'no temperature change occurs'. Thus reaction 9 was the only instance in the partial-direction mode where some of the illusory errors fell into the cued area; in all other instances illusory errors were of the non-cued variety. Thus since cueing of positive observations brings about enhanced

perception as reported in Section V b) (iv), it would seem that the same situation applies to the detection of illusory 'observations', cueing enhances them.

VI

The ancillary tests with possible relationship to observational attainment

Two such tests were administered as part of the test battery; these were a chemistry theory test and a hidden figures test. The former was included to investigate any relationship between the level of chemistry theory attainment possessed by pupils and their observational attainment; the latter looked at an aspect of cognitive style felt to be pertinent. The results and a discussion follow.

a) The chemistry theory test

This was of the multiple-choice type, containing 30 items. When the test had been administered and marked, indices of difficulty and discrimination were calculated and items having difficulty indices between 0.25 and 0.80 and discrimination indices greater than 0.195 were used in the subsequent analysis. (The indices are shown in Appendix B vii). The details of the subsequent analysis showing the relationship of the observational attainment of the pupils with respect to levels of chemistry theory attainment and modes of task definition are displayed in Table 29.

(For this purpose the population was divided into approximately top, middle and bottom thirds with respect to levels of chemistry theory attainment).

An examination of the data in Tables 29 and 30 shows that there is no significant relationship between the observational attainment levels produced by pupils with differing levels of chemistry theory achievement. Although one might have thought that increased awareness of theoretical considerations might have led to better directed and more successful observations, in the sense that pupils with more proficiency in theoretical matters would have a better idea of what to look for, this is clearly not happening, and again it is only the modes of task definition that have significant bearing on observational attainment.

Table 29 The relationship between levels of chemistry theory attainment and observational attainment according to modes of task definition

		Mean scores on the observational test with respect to mode			
		Open-ended	Partial-direction	Check-list	
Chemistry theory levels	Top third (11-19)	$\bar{x} = 24.60$ S.D. = 4.85 n = 15	$\bar{x} = 25.70$ S.D. = 2.56 n = 17	$\bar{x} = 27.60$ S.D. = 2.99 n = 17	$\bar{x} = 26.02$ S.D. = 3.65 n = 49
	Middle third (9-10)	$\bar{x} = 25.50$ S.D. = 4.25 n = 13	$\bar{x} = 24.76$ S.D. = 2.81 n = 17	$\bar{x} = 25.40$ S.D. = 3.06 n = 10	$\bar{x} = 25.18$ S.D. = 3.29 n = 40
	Bottom third (under 8)	$\bar{x} = 24.25$ S.D. = 3.78 n = 20	$\bar{x} = 25.00$ S.D. = 2.88 n = 14	$\bar{x} = 26.69$ S.D. = 2.72 n = 20	$\bar{x} = 25.42$ S.D. = 3.27 n = 57
		$\bar{x} = 24.69$ S.D. = 4.15 n = 48	$\bar{x} = 25.16$ S.D. = 2.69 n = 48	$\bar{x} = 26.76$ S.D. = 2.91 n = 50	

n = 146

(Maximum score on chemistry theory test was 20)

To enquire into the significance of these data, a two-way analysis of variance was performed and the results follow in Table 30.

Table 30 Two-way analysis of variance, observational attainment with respect to modes and chemistry theory levels

Source of variation	SS	df	MS	F	Significance
Modes of task definition	114.2	2	57.1	5.05	0.01 level
Chemistry theory levels	18.3	2	9.15	0.81	N.S.
Interaction	35.1	4	8.78	0.78	N.S.
Within cells	1550.3	137	11.31		
Total	1719.9	145			

$p(0.01 \text{ level and } 2/145) = 4.61$

Essentially this confirms what was found in the 1971 study, that the practical mode represents a type of chemical achievement which is independent from that in the theoretical aspects of the subject.

This is also in full accord with the factor analytic study by Ben-zvi, Hofstein, Samuel and Kempa (1977) into modes of instruction in High School chemistry, who found that practical work can be subdivided, factor wise, into three distinct modes, observational ability, manipulative ability and problem-solving ability, but cognitive achievement in chemistry was not a significant factor in determining ability in the practical domain.

b) The hidden figures test

Observational behaviour is linked to certain psychological characteristics, and it was felt that the notion of field-dependence /independence as a cognitive style would be worth investigating.

Thus the opportunity for incorporating, in an exploratory way, the hidden figures test into the test battery for this part of the study arose from an investigation at Keele into the interaction between cognitive styles and different learning approaches and strategies.

This investigation is still in progress, but reference has been made to it in "Cognitive Development Research in Science and Mathematics"; Archenhold, Driver, Orton and Wood-Robinson (1980).

It was felt that field-independent pupils who have the ability to look at aspects of a complex situation independently of distractions from the background should find the task of discriminating between perceptual stimuli reasonably easy. The field-dependent pupils, when faced with the same stimuli, could find it difficult to extract specific items from the distracting background.

i) Results of a pilot, small-scale study into the relationship between observational attainment and field-dependence/independence cognitive style

When the hidden figures test was applied to the population available, the number of pupils completing what, it must be pointed

out, was a timed test, was greatly reduced to only 62, but the data which follow in Table 31, support the hypothesis that field-independent pupils should have an advantage over the field-dependent ones. No account is taken here of the different modes of task definition because of the reduced sample numbers, and the population is divided into approximately top and bottom halves.

Table 31 Mean scores on the observational attainment test according to hidden figure test levels

Mean scores on the observational test	
Upper hidden figure test level	$\bar{x} = 26.20$ S.D. = 3.22 n = 35
Lower hidden figure test level	$\bar{x} = 24.29$ S.D. = 2.84 n = 27

ii) In the light of these data, it was decided to mount a further 'one-shot' case study in a more elaborate way, to investigate further what had been tentatively brought out, i.e. that field-independent pupils are at an advantage over field-dependent ones in terms of observation in practical chemistry.

For this investigation, a much larger total population drawn from 13 schools was used. The total sample size was 673, of whom 456 satisfactorily completed the timed hidden figures test. (In the light of the pilot study referred to above, it was decided to extend the time allowed for the test from 12 to 17 minutes, since this would give a larger population and would not invalidate the essential nature of the test). Only pupils completing the extended time test were included in the subsequent analysis.

Table 32 gives details of the population used for the larger 'one-shot' case study, incorporating the observational test, the colour-vision test (employed as an essential check) and the hidden figures test. The observational test included all 12 test items as originally designed. Since there has been no sex bias found in the earlier parts of this study, the population is given as a whole, and not divided into boys and girls. (Appendix B (viii) shows the instruction sheet sent to the schools).

Table 32

Population participating in the enlarged
'one-shot' case study

School	Population
De Aston, Market Rasen	44
North Kesteven School	29
Cherry Willingham School	35
Hereford School, Grimsby	91
William Farr School, Welton	48
Workington Grammar School	80
Salterbeck School	22
Caistor Grammar School	41
Banovallum School, Horncastle	19
Matthew Humberstone School, Cleethorpes	65
Whitgift School, Grimsby	41
Frederick Gough School, Scunthorpe	98
South Park School, Lincoln	80
Total	673

The results for this larger investigation into the effect of field-independence/dependence on observational attainment are given in Table 33. The population for this purpose was divided into three approximately equal groups representing top, middle and bottom scores, on the hidden figures test.

Table 33

Mean scores on the observational attainment test according to hidden figure score levels and mode of task definition

		Mean scores on the observation test according to mode			
		Open-ended	Partial-direction	Check-list	
Hidden Figure test levels	Top third (15-18)	$\bar{x} = 26.00$ S.D. = 3.29 n = 52	$\bar{x} = 25.80$ S.D. = 3.63 n = 60	$\bar{x} = 28.30$ S.D. = 3.16 n = 44	$\bar{x} = 26.57$ S.D. = 3.46 n = 156
	Middle third (12-14)	$\bar{x} = 23.95$ S.D. = 3.70 n = 56	$\bar{x} = 24.57$ S.D. = 3.86 n = 49	$\bar{x} = 27.30$ S.D. = 3.47 n = 60	$\bar{x} = 25.41$ S.D. = 3.66 n = 165
	Bottom third (Below 12)	$\bar{x} = 22.59$ S.D. = 3.73 n = 49	$\bar{x} = 24.13$ S.D. = 3.04 n = 44	$\bar{x} = 25.57$ S.D. = 3.39 n = 42	$\bar{x} = 24.02$ S.D. = 3.40 n = 135
		$\bar{x} = 24.20$ S.D. = 3.57 n = 157	$\bar{x} = 24.92$ S.D. = 3.53 n = 153	$\bar{x} = 27.10$ S.D. = 3.35 n = 146	

(Maximum score = 18 on the hidden figures test)

(Maximum score = 36 on the observational test)

To enquire into the significance of these differences, a two-way analysis of variance was carried out and the results are shown in Table 34.

Table 34

Two-way analysis of variance, observational attainment with respect to modes and hidden figure test levels

Source of variation	SS	df	MS	F	Significance
Treatment modes	681	2	340.5	27.24	0.001
Hidden figure test levels	469	2	234.5	18.79	0.001
Interaction	71	4	17.75	1.42	N.S.
Within cells	5581	447	12.48		
Total	6802	445			

$$p(0.001 \text{ level and } 2/455) = 6.91$$

An examination of the information in Tables 33 and 34 clearly shows that not only does the mode of task definition play a significant part in determining levels of observational attainment for the reasons which have been elaborated earlier in the thesis; but there is also a significant part played by the extent to which pupils are either field-independent or dependent.

The field-independent pupils, i.e., those who score highly on the hidden figures test since they have the ability to discriminate the figures from within the complex geometrical background, score more highly on the observational test in chemistry. Thus the hypothesis that was made earlier, i.e., that field-independent pupils should have an advantage over field-dependent pupils is quite clearly justified by these results.

Whilst, as in previous cases, we cannot perform detailed analysis on the partial-direction mode, since it is an admixture of some cued and some non-cued observations, we can compare the open-ended and check-list modes further.

A field-dependent pupil should find the open-ended mode a more difficult and demanding one than the field-independent pupil, since the former has no help to lead him to make the correct observations in that mode. Therefore the task of selecting one particular stimulus from a complex background is inclined to be difficult. In the check-list mode, however, the field-dependent pupil has been given considerable help in looking for the hidden stimuli. It is almost as if, in the case of the hidden figures test, some of the lines of the 'hidden figure' have been made quite prominent. Therefore, if this hypothesis is correct, one should expect a larger discrimination between the scores of the top and bottom hidden figure test groups representing the field-independent and field-dependent pupils respectively, on the open-ended approach, as compared with the check-list group. That this clearly is so is observed when it can be seen that the differences between the mean scores of the top and bottom hidden figures groups (representing the field-independent and field-dependent groups, respectively) is 3.41 on the open-ended mode and somewhat less at 2.73 on the check-list mode.

Therefore, the field-dependent pupils do find the open-ended mode a more difficult type of task definition than the check-list mode. (The fact that the check-list mode scores are higher, for equivalent field-dependent/independent groups is, of course, more a feature of the effect of the mode of task definition rather than of cognitive-style differences).

Another point of interest which arises from the intrinsic difficulty of the open-ended mode with respect to field dependent pupils is this. One would expect a field-independent

pupil to be less influenced by modes of task definition than a field-dependent pupil. If we, therefore, examine the difference between the open-ended and check-list mode scores for the high scoring hidden figures test group as against the low group, we have a difference in terms of the field-independent (high scoring) of 2.30, whilst at the other end of the scale, i.e., at the field-dependent end, the difference is greater, i.e., it is now 2.98. This reinforces the notion that a field-dependent pupil derives more assistance from the use of the check-list than does the field-independent pupil.

Thus whilst it can be seen from this section devoted to a consideration of ancillary tests, that the level of chemistry theory achievement possessed by a pupil has no significant effect on his observational ability, it can be firmly stated that the extent to which a pupil's cognitive style is representative of either the field-independent or field-dependent type is of significant importance in helping to decide his level of observational attainment in chemistry, and which mode of task definition is liable to be the most helpful.

Summary of the present chapter

This part of the study set out to investigate the effect that three different modes of task definition, namely the open-ended, partial-direction and check-list modes, might have on pupils' observational attainment when subjected to a standardised test of observation in chemistry. It was found that the check-list approach produced attainment levels which were superior to the other two at the 0.001 level of significance. The partial-direction and open-ended approaches produced attainment levels which were similar in magnitude.

However, the partial-direction mode produced a situation where pupils developed an enhanced level of perception towards those observations which received cueing, but in those areas for which no cueing was provided, a degree of 'blinking' was observed producing a far lower level of observational attainment. In this respect, the balance between enhancement on one hand and depression of the other, put the overall performance of the partial-direction mode pupils slightly ahead of the open-ended pupils, but not significantly so.

The study showed that although the various stimuli were presented within one and the same level of difficulty, it was found that, in this type of multi-stimuli situation colour changes were somewhat easier to detect than changes in the other three perceptual areas, namely solids, thermal and gaseous. This ease with respect to colour detection led to colour cueing in the check-list mode being completely superfluous.

Two types of error were made by pupils following all three modes of task definition, namely errors of omission and errors of an illusory type. In the former, pupils failed to report stimuli and in the latter reported observations which had no factual foundation. In terms of omission errors, the frequency of these reflected the positive attainment, i.e., the check-list approach was least prone to errors of omission. In the case of illusory errors, however, the check-list provided by far the greater number of illusory errors, and it was suggested that this in itself may have been one of the factors contributing to the success of the method. Illusory errors were not constant across all four perceptual areas, but the non-visual aspects, i.e., olfactory

and haptic perception, were found to be especially vulnerable to this type of error.

As observational tasks became more complex in terms of the number of different stimuli there to be detected, so detection efficiency was reduced. This was not in the form of a gradually decreasing standard of efficiency, but once four or more stimuli were presented the detection rate fell off suddenly. It was also found that when the number of stimuli available for detection, which we defined as the task-complexity value, was high, so the check-list mode proved to be far superior to the open-ended mode, whereas at low task-complexity values there was little to choose between open-ended and check-list performances. In terms of illusory errors, these did not seem to relate to task-complexity values but were dependent more on the type of real stimuli already present for detection.

It was also shown in the chapter that observational attainment, as measured by the practical test, was independent of the level of chemistry theory attainment level as measured by a multiple-choice chemistry test. However, it was shown that the type of cognitive style known as field-dependence/independence was a determining factor where observational attainment in chemistry was concerned. The hidden figures test was used to obtain an indication of the degree of field-dependence/independence possessed by a pupil. Pupils who were field-independent performed significantly better on the observational test, irrespective of mode of task definition, than pupils who were predominantly field-dependent as measured by high and low scores respectively on the hidden figures test. In addition it was also found that field-independent

pupils had a greater advantage when faced by open-ended questioning than they did when using the check-list mode.

CHAPTER 6 THE TEACHING STUDY

I Introduction

The previous section of the study was concerned with exercises that examined the relative effectiveness of three modes of task definition on observational competence in the practical aspects of chemistry, but it did not concern itself with the question of whether observational competence can be developed by means of appropriate learning strategies.

It is evident from the literature and from the opinions of many science educationists, that the development of observational skills must be seen as an important curricular objective within the framework of practical work. It is equally evident, however, that so far curriculum developers and educationists in general have seen the development of this ability to be more the by-product of practical work in general, rather than the result of a deliberate attempt to improve observational ability and enhance pupils' powers of observational discrimination. The reason for this is no doubt that teaching strategies deliberately designed to enhance observational skills, have so far not been explored.

In the context of the present study it seemed appropriate to ask whether, through a careful exposure to different types of observational experience, pupils' observational attainment could be enhanced or promoted. In other words, can different approaches to observational functioning in the context of practical work in chemistry lead to different observational competences?

In view of the previous findings concerning the relative effects of the three different modes of task definition,

namely the open-ended, the partial-direction and the check-list, on observational attainment, it was thought desirable, within the framework of this part of the study, to incorporate these modes of task definition into genuine teaching strategies. Thus one could examine how the different teaching strategies, i.e., those using different modes of task definition for the conduct of observational activities, affected or could affect ultimately, pupils' observational attainment under different conditions.

The assumption can be made (and is fully justifiable in terms of accepted observations from educational psychology) that any type of learning must, in the first instance, lead to the acquisition of skills that are specific to that type of learning. This specificity applies not only to the tasks to be accomplished, but also to the conditions under which the tasks are to be achieved.

In terms of the use of the three modes of task definition in the design of learning experiences, this could mean that the open-ended approach, might be expected to act as 'discovery learning', since Ausubel (1963), has defined discovery learning as follows: "... the principal content of what is to be learned is not given". Bruner's (1961) hypothesis is that when a person learns by discovery techniques, he gains in his ability to organise information. Thus pupils following this mode could be at an advantage when faced by an open-ended test, whereas pupils who had not had this opportunity for self-organisation might be at a disadvantage when observing in an open-ended test situation.

If we now consider the pupils who follow the partial-direction approach, two alternative hypothesis suggest

themselves. Either the pupils will experience and be affected by the 'blinkering' effect (reported in Chapter 5) in both the teaching and learning situations, and produce inferior learning behaviour in terms of what they observe; or they could use the partial-direction cues to build up their own innate motivating 'check-list'. This aspect of 'guided discovery' learning was shown by Kersh (1962), to be superior in that it did increase student motivation.

With respect to the check-list mode, one hypothesis is that exposure to this teaching approach could produce in the pupils an awareness of the full range of observations that can be made; and that this awareness would ultimately carry over into testing situations. The converse would be to assume that continuous exposure to a check-list provides a 'crutch' of a type which hinders the learner from developing his own framework of observable items. The work by Dorsel and Cundiff (1979), referred to earlier in the thesis would certainly support the latter hypothesis.

Against this kind of consideration, which presents several alternative hypothesis, all of which have a bearing on the design of the teaching study, a strategy needs to be developed to encompass them all as far as is possible.

The strategy for the teaching study

a) Since several alternative hypothesis present themselves for consideration, then an ideal strategy should be able to enquire into the interaction between the three teaching modes and the three modes under which testing can be carried out.

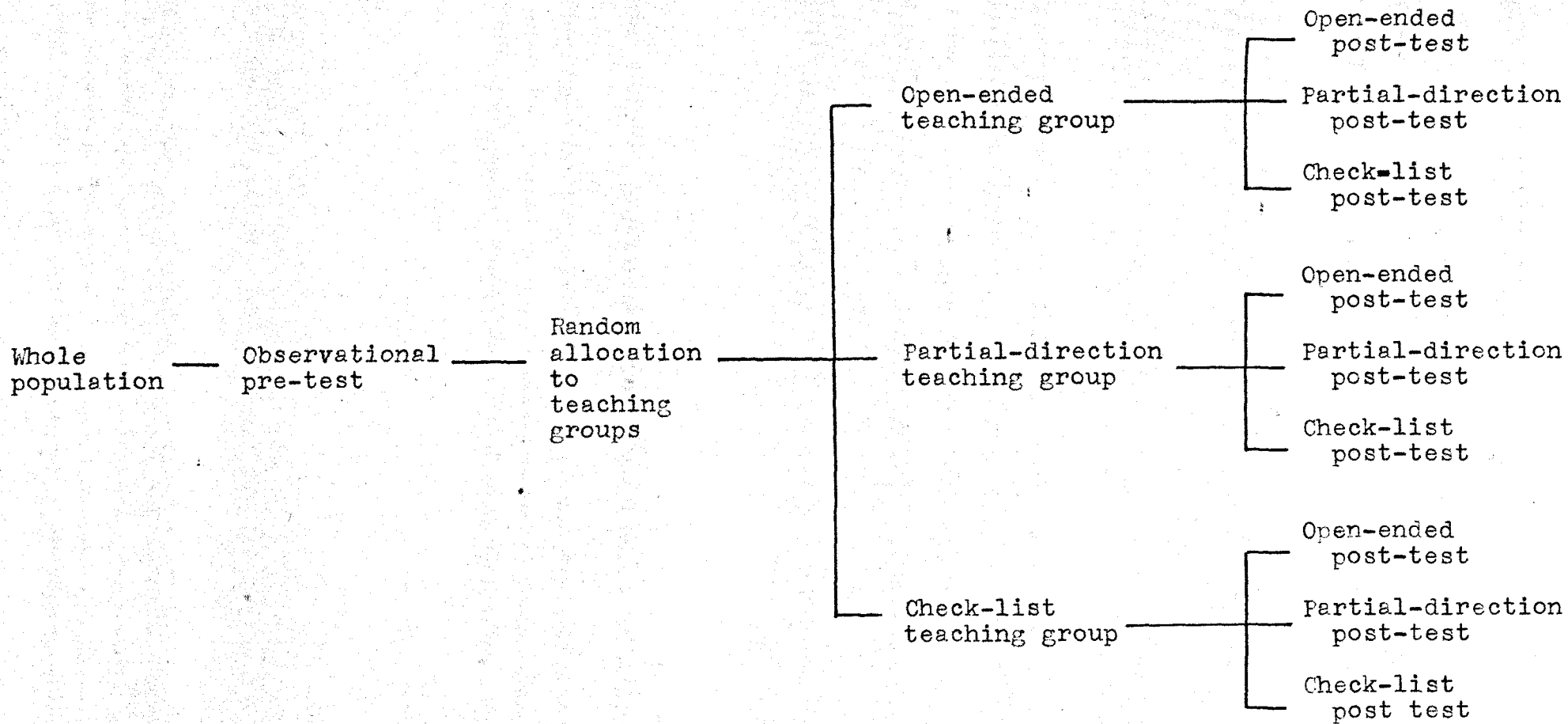
An ideal strategy is depicted diagrammatically in Figure 12, ideal in the sense that the effect of each

teaching mode can be monitored by being subjected to each of the three testing modes. This, for example, would enable one to discover if the check-list mode did act to increase awareness of observational possibilities or whether it acted in the role of a 'crutch', since testing by an open-ended mode, where the 'crutch' was removed, would show a deterioration in observational attainment as compared with check-list testing where the 'crutch' was still in place.

An observational pre-test was considered essential in order to be able to monitor the initial observational attainment levels of the pupils so that one could be certain that the treatment/testing groups were comparable in this respect before the start of the teaching schemes.

Figure 12

An idealised strategy for the teaching study



b) Application of this idealised strategy to a teaching situation

i) The choice of observational stimuli

A genuine teaching sequence, in which the conditions for observational activities are considered as experimental variables, cannot be carried out in isolation from normal laboratory teaching. The time requirement for a study of this nature means that it cannot, in fact, be developed as a separate experiment in its own right; instead it must be carried out within the framework of normal class teaching. This immediately imposes constraints which arise from the interaction of what would best serve the research situation and what in fact the 'classroom' situation will allow.

For example, one would like to develop a systematic programme of purely observational instruction, where the variables would relate to concepts like stimulus-intensity, task-complexity values and perceptual fields; but this is not possible in the classroom situation, since the teaching syllabus appropriate to the pupils following the programme determines the perceptual range and, to a large extent, the type of observational phenomena to be included. It has to be recognised that in the process of practical chemical education, observation is not an end in itself; but a means to an end. Thus one finds oneself limited to those observations which are related to the cognitive demands of the pupils' course.

ii) The choice of population

The major question here, initially, was the availability of pupils for participation in this type of investigation. Research into the teaching of observation

would certainly need at least a medium-term investigation to do it justice simply because of the range of phenomena which merit consideration. Schools are reluctant to allow pupils close to their public examinations to take part in a medium-term investigation as envisaged above. At best, it is pupils in the lower age range who can be called upon. As was found out during preliminary enquiries and approaches to schools, the only available population came from second-years in one five-year 11-16 course (the author's own school). These pupils had followed a Combined Science course in their first year at school and had recently started to do separate Chemistry in Year 2.

This meant that one had to avail oneself of a population of young pupils who were relatively uninitiated in the field of chemistry as such. However, this was not seen as a disadvantage since the pupils had not been influenced by excessive experience of practical chemistry.

iii) Pupil populations for participation in the study

If one accepts that between 25 and 30 pupils are a reasonable number to be included in a treatment-testing group, inspection of Figure 12 shows that, since there are 9 such groups, about 250 pupils would be required to implement the strategy outlined.

Because of the nature of the study it was necessary to confine it to the author's own school, De Aston School, an 11-18 comprehensive school in Lincolnshire. Although this school has a total annual intake of approximately 180 pupils, only about a half of these were available. Thus the 'available' population (i.e., that accessible for this study) was only about 85-90 pupils per year. The further restriction, referred to above, was that only second-year pupils could be

involved in the study. Thus in any one year the total population available for the study amounted to only one third of the requirement for the overall study outlined in Figure 12. To overcome this problem, the decision was taken to conduct the study in three separate phases, using 2nd year groups in those three successive years.

This took the following form. In each of the three successive years, all three teaching programmes: namely open-ended, partial-direction and check-list were used, involving in each case about $\frac{1}{3}$ of the available year population. The testing at the end of the teaching programmes, however, was confined to only one of the testing procedures each year, i.e., open-ended testing in the first year, partial-direction in the second and check-list in the third.

An alternative approach would have been to use only one teaching approach per year and test each year by all three testing modes, applying each mode to $\frac{1}{3}$ of the year population. This alternative was rejected in order to minimise year to year variations in the pupils' responses to the different learning approaches.

The decision to conduct the experiment over three years was, of course, a compromise, but one that was unavoidable in the circumstances. However, since over the period of the study the pupil intake into the school was reasonably stable, and since no major curricular changes took effect in that part of the school, with identical conditions being established for the administration of the teaching programmes, the phasing of the teaching study over three years is not considered inferior to a situation where the total study would have been undertaken in one 'grand-slam'.

However, it was felt necessary and desirable to show specifically that the different year populations were equivalent, so that any differences in observational attainment which arise during and at the end of the learning experiences could not be attributed to basic population differences. To enable equivalence to be established two tests were applied in addition to the observational pre-test referred to on page 127. These were :

- i) the AH4 test of general intelligence, and
- ii) the 'Bristol' test of scientific achievement.

The first test, that of general intelligence, although a global test rather than one specifically related to observational competence, was included to ensure that pupils were of a similar degree of general intelligence, so that any variations in observational learning between the treatment groups could not be ascribed to differences in general intelligence.

The second test, the 'Bristol' test, is a test of a general scientific nature and this gave a more scientifically biased account of the pupils' abilities than could be derived from AH4 measurements.

By combining the results of these two tests and of the observational pre-test, one can have a reasonably accurate picture of the degree of equivalence of the population samples used.

c) The choice of teaching material and adaptation of it to the three modes of presentation

i) Choice of material

As has already been pointed out, the study was conducted using 2nd year secondary school populations at the beginning of an 'O' Level/C.S.E. chemistry course. The

choice of teaching material, then, was essentially dictated by the existing school chemistry syllabus, which, for the first year of the subject, pursues an exploratory chemistry course, adapted from a 'Nuffield' approach. The particular topics included in the two-term teaching course (the length of the time allocated to the study in each of the three years) are as shown in Table 35.

Table 35

List of topics included in the introductory chemistry course at De Aston School, Market Rasen

Topic	Time allocation (weeks)
1. The bunsen-burner	1
2. States of matter	2
3. Purification processes i) Distillation ii) Crystallisation	3 1
4. Chemical and physical changes, i.e., heating substances in air and out of air	4
5. The composition of air, leading to oxygen as the 'active' component	3
6. Burning elements in oxygen - use of indicators	4
7. Preparation of oxygen from hydrogen peroxide	2
8. Preparation of oxygen by thermal decomposition	2

All of these topics were characterised in this introductory course by being largely laboratory-based. Practical work to be done was mainly non-quantitative in nature, involving a wide range of simple experiments. The qualitative nature of the experiments gave considerable scope to the observational content which could be included; therefore the choice of teaching material was thought to be pertinent and suitable for this type of teaching study.

ii) Adaptation of the teaching materials to represent the three modes of task definition

The practical implementation of the three different modes of task definition was facilitated by the design of 'practical booklets' for each of the different modes chosen. In all other respects, apart from modal ones, the teaching approach used for the three groups was identical.

The particular advantages of using booklets were as follows. First, they allowed a clear specification of the conditions under which observations were to be made by the pupils; second, they gave information about apparatus to be used and specified what manipulation was necessary; third, they were convenient for the pupils to record their observations in and were available to the author for the continuous assessment of observational attainment throughout the study.

With regard to the last point, it is clear that the main purpose of the study was to examine the effect of the exposure to different modes of task definition during the learning process involved in normal school practical chemistry on subsequent observational behaviour as measured by post-tests. However, it was thought desirable not only to develop a series of post-tests whereby this particular effect could be established, but also to monitor closely the pupils' observational attainment during the course work. Thus the continuous assessment of course-work booklets enables the effect of modes of task-definition on normal laboratory observation to be examined.

III The development of test materials

a) The observational pre-test

For the purposes of the pre-test, the distinction was not made between open-ended, partial-direction or check-list

approaches. Instead an open-ended approach was chosen. In terms of the measurement technique involved it was the most neutral approach since it gave neither cueing nor 'blinkering' opportunities.

The design of the test was such that it contained 22 different observational stimuli distributed through 10 exercises. The Table which follows shows the distribution of observations throughout the ten test-items in terms of the perceptual field used together with task-complexity values involved. Details of all chemicals used, together with a copy of the test booklet, which included manipulative instructions and space for answers, are displayed in Appendix C (i).

Table 36

Details of observational phenomena included in the observational pre-test

Test-item numbers	Perceptual fields				Task-complexity value
	Colour	Solids	Thermal	Gaseous	
1	2				2
2		1			1
3		1			1
4			1		1
5		2		2	4
6		2			2
7				1	1
8	1	1			2
9		1	1	2	4
10	2	1		1	4
Total	5	9	2	6	22

It is to be noted that all stimuli were presented at the 100% detection level, using data from Chapter 4, and the

task-complexity values were mainly below the value of 4. This was done to ensure that at this early stage the test was, whilst standardised, not difficult. (It will be remembered from the results of Chapter 5, pages 106-107, that once the task-complexity value rose above 3, the difficulty level increased sharply, hence the fact that 80% of the test was below this level).

b) The teaching-scheme booklets

Three different sets of booklets, it will be remembered, were needed, corresponding to the three modes. Open-ended mode booklets normally gave a very general instruction as to the conduct of an experiment and basically asked pupils to record all observations made by them. No extensive overt cueing to any observations was given. For example, in section 3.21 of the booklets, pupils were asked to add impure X (contaminated sodium chloride) to water and shake. They then were asked to report what happened.

In the partial-direction mode booklets, however, for the same example (3.21) the question "Does all the solid dissolve?" was posed, introducing the element of partial-direction. In the partial-direction booklets it was made clear that all other observations, as well as the overtly cued one, were to be given.

The third approach corresponded to the check-list approach. In the check-list booklets, following general manipulative instruction, check-lists of the type shown in Table 37 were presented to the pupils. On each check-list the pupils were required to tick off all phenomena which they had observed and then use the check-list to write up the experiment.

Table 37

Example of the type of check-list used

Check-list for Experiment 3.21

Does X	Evaporate Condense Melt Solidify Sublime Leave a residue Give a smell Dissolve Refuse to dissolve	?
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Copies of the booklets are given in Appendix C (ii) together with the continuous assessment marking schedule.

It must be pointed out that rigid adherence to the three formats was not always possible, but every effort was made to represent faithfully each of the three modes.

c) The post-tests

It was decided to use for this purpose the tests developed and used in the task definition study reported in Chapter 5. This was done for two main reasons.

First, it obviated the necessity to develop an entirely new and untried set of instruments and allowed the use of an instrument about which a good deal of information is already available. Second, since these tests are independent of the actual teaching sequences used, no unforeseen and undesirable transfer of information needed to be safeguarded against, nor could any take place. The test specification and test booklets used are shown on page 78 of Chapter 5 and in Appendix B (iv).

d) The 'Bristol' test

This test is supplied in a number of variants, and it was decided to use Level 5, Form A (a copy of this is shown in Appendix C (iii)) as this was most suitable for the particular second year age group.

IV Administrative details of the teaching study

a) The population used

As was stated earlier in the Chapter, the population used comprised three successive 2nd year groups from De Aston School, Market Rasen. Table 38 shows the identity of the populations together with the testing mode used in each of the successive years. (The administrative system in the school uses a year code-letter to define each year group and this, too, is given).

Table 38

Details of the populations involved and testing modes applied

Year letter	Year	Population size	Testing mode
P	1976-77	78	Open-ended
R	1977-78	82	Check-list
S	1978-79	63	Partial-direction

Ages between 12.0 and 13.11 years

b) The operational details of the study

i) Pencil and paper tests ('Bristol' and AH4 tests)

These were administered under examination conditions, and the conditions stipulated in the test rubrics were adhered to in terms of time allowance and mode of conduct.

ii) Observational course-work

This was carried out in normal chemistry periods (one double period of 70 minutes per week) and normal laboratory teaching conditions applied, i.e., pupils were allowed to talk and discuss what they were doing with each other and the teacher. They worked at their own rates through the booklets, which were used whenever practical work had to be done. The work was marked and corrected in the usual manner.

In order to facilitate the operation of the study, each of the three second-year classes in years P and R were allocated to one particular teaching mode. These modes were given code letters in order to prevent the chance of pupils responding according to the name of the mode. Thus, the open-ended approach was denoted by A, the partial-direction approach, by B, and the check-list approach, by C. It will be seen from Table 38 that year S was somewhat smaller than the two previous years and only supplied 2 teaching groups. In this instance, pupils in each teaching group followed 2 teaching approaches, i.e. one group followed Modes A and B, and the other Modes B and C.

It was reasonably easy to separate the two mode groups in the laboratory, and the author, who personally supervised this part of the teaching scheme, ensured that pupils in this situation following one mode did not communicate with pupils following the other. In all three years (P, R & S), the author, or a colleague working in close liaison with him, ensured that the correct teaching booklets were used, and followed rigorously. All groups in all years were asked not to communicate information about the guidance procedures to pupils following the other approaches.

iii) The practical tests, i.e. pre- and post-tests

Similar conditions to those used in the work described in Chapter 5, page 87, were applied. Reactions were carried out in standard test-tubes marked at the 1" and 2" levels, reagents were positioned at convenient locations in the laboratory, no time limit was imposed and examination conditions were maintained throughout both tests.

Results and discussion of the teaching study

In Chapter 5 it was shown that the different modes of task definition: namely the open-ended, partial-direction and check-list modes, when applied to the conduct of practical observational

experiments had a significant effect on the levels of observational attainment in the 'one-shot' case study reported there.

It was also suggested in the present Chapter that if these modes formed the basis of three actual teaching approaches, then perhaps some difference in observational attainment might arise in pupils following the different approaches.

The evaluation of the three teaching approaches can, in fact, be divided into two distinct areas. First, there is the question of the overall analysis, i.e. how do the pupils who undergo different teaching approaches perform in relation to the subsequent post-tests? Second, we need to consider the question of the performances of the different teaching groups in relation to the observational tasks which form part of the teaching sequences, in order to find out if these performances differ from, or are similar to, one another.

However, as was shown in Section II, the actual execution of the study called for the spreading of the research across three successive second-year populations in the same school. Thus a problem of population equivalence arose and this issue is now examined before proceeding to the results of the post-test and observational course work.

a) The equivalence of the populations used in the study

It will be remembered that three tests to enquire into population equivalence were applied; namely the AH4 test of general intelligence, the 'Bristol' test of scientific achievement and the observational pre-test. These test results are now examined.

i) The AH4 test of general intelligence

The results of this test are shown in Table 39 and this is followed by Table 40 which shows the

results of the two-way analysis of variance carried out on the data in Table 39. (The year groups are designated by their year letters: P, 1976-77; R, 1977-78; S, 1978-79).

Table 39

The results of the AH4 test used to investigate equivalence in terms of general intelligence

		Mean scores on the AH4 test according to allocated treatment group			
		Open-ended	Partial-direction	Check-list	
Year Group	P	$\bar{x} = 68.80$ S.D. = 15.37 n = 20	$\bar{x} = 61.95$ S.D. = 11.63 n = 21	$\bar{x} = 68.04$ S.D.=15.12 n = 23	$\bar{x} = 66.28$ S.D.=14.05 n = 64
	R	$\bar{x} = 67.64$ S.D. = 9.91 n = 17	$\bar{x} = 72.38$ S.D. = 9.95 n = 21	$\bar{x} = 68.09$ S.D.=11.37 n = 22	$\bar{x} = 68.32$ S.D.=10.45 n = 60
	S	$\bar{x} = 73.16$ S.D. = 11.91 n = 18	$\bar{x} = 73.66$ S.D. = 10.75 n = 21	$\bar{x} = 67.58$ S.D.=12.56 n = 19	$\bar{x} = 71.51$ S.D.=11.70 n = 58
		$\bar{x} = 69.87$ S.D. = 12.55 n = 55	$\bar{x} = 69.33$ S.D. = 10.76 n = 63	$\bar{x} = 67.92$ S.D.=13.07 n = 64	

Total Sample Size for this test = 182

\bar{x} = Mean

S.D. = Standard deviation

Table 40

Two-way analysis of variance of the above data. AH4 scores with respect to year groups and allocated treatment groups

Source of Difference	SS	df	MS	F	P
Year differences	853	2	426.5	2.665	NS at 0.05
Treatment Groups	123	2	61.5	0.384	N.S.
Interactions	1186	4	296.5	1.853	NS at 0.05
Within Cells	27696	173	160.0		
Totals	29858	181			

SS = Sum of squares df = degrees of freedom

MS = Mean squares

$p(2/180) = 3.00$ for significance at the

p = Significance level 0.05 level

An examination of this data shows that there is no significant difference in terms of general intelligence in the groups assigned to the three treatment modes. Thus if there are any subsequent differences in observational attainment after exposure to the treatment modes, these differences cannot be attributed to variations in general intelligence, but must be ascribed to the teaching or testing procedures used.

However, it will be noted that, in terms of general intelligence, there is a slight upward trend from year P to Year S. This is not an age-related effect, since all participants in the teaching scheme were in their second year of a secondary school chemistry course; thus whilst the difference between treatment groups is clearly non-significant, that between the year groups, although it fails to reach the 0.05 level of significance, it is not far off.

ii) Results of the 'Bristol' achievement test

Whereas the AH4 test was a global test of general intelligence, this test has a more scientific bias and its results are now examined.

The data is given in the age-standardised form and appears in Table 41. This is followed in Table 42 by the results of a two-way analysis of variance based on the 'Bristol' test data.

Table 41 (see next page)

Table 41

Mean standardised scores on the 'Bristol' test according to the treatment group to which the pupils were subsequently assigned and the year-group

		Standardised scores on the 'Bristol' test according to the allocated treatment group			
		Open-ended	Partial-direction	Check-list	
Year Group	P	$\bar{x} = 102.29$ S.D. = 8.51 n = 21	$\bar{x} = 100.75$ S.D. = 8.63 n = 24	$\bar{x} = 104.24$ S.D. = 7.56 n = 25	$\bar{x} = 102.46$ S.D.=7.53 n = 70
	R	$\bar{x} = 106.00$ S.D. = 6.32 n = 21	$\bar{x} = 108.11$ S.D. = 7.07 n = 26	$\bar{x} = 105.13$ S.D. = 6.08 n = 24	$\bar{x} = 106.46$ S.D.=6.89 n = 71
	S	$\bar{x} = 112.41$ S.D. 6.98 n = 17	$\bar{x} = 108.11$ S.D. = 7.85 n = 17	$\bar{x} = 108.23$ S.D. = 10.15 n = 17	$\bar{x} = 109.59$ S.D.=8.03 n = 51
		$\bar{x} = 106.50$ S.D. = 7.42 n = 59	$\bar{x} = 105.48$ S.D. = 6.90 n = 67	$\bar{x} = 105.59$ S.D. = 7.91 n = 66	

Table 42

Two-way analysis of variance - 'Bristol' scores with respect to year-groups and treatment-groups

Source of differences	SS	df	MS	F	P
Year differences	1545.6	2	772.8	11.95	>0.001
Treatment groups	39.58	2	19.79	0.306	N.S.
Interaction	433.32	4	108.33	1.675	N.S.
Within cells	11835.5	183	674.67		
Total variation	13854.0	191			

This test leads to a very similar result to that of the AH4 test in that (a) the differences between the allocated treatment groups are small and non-significant and (b) the differences between the three year groups show that the same trend is in the previous analysis, but with a much more marked

degree of difference. This is borne out in both Table 41 and Table 42 and shows that in terms of either scientific ability or experience year S > R > P

iii) The observational pre-test

The two measures we have just examined obtained from the AH4 and 'Bristol' achievement tests, are basically a measure of intellectual functioning, but as can be gathered from Chapter 5, pages 111-114, there is some considerable doubt as to whether there is any significant relationship between intellectual performance and attainment in a practical test of observational attainment,

The basis of this finding was a lack of a correlation between chemistry theory results and observational attainment. Thus one would expect that the AH4 and 'Bristol' tests, although they indicate equivalence in terms of intellectual facility between the three treatment groups, still may not give us information on the observational attainment status of the pupils, hence it was felt necessary to design a specific test of observational attainment to be administered before the start of the teaching programme.

The test was one of observational attainment in chemistry and is described fully in Section III, page 134 and in Appendix C (i). In the test there were 22 stimuli to be observed in the 10 reactions chosen, and the observation was done under identical conditions by the pupils using the open-ended mode. This mode was chosen so that no form of bias should appear in the testing situation.

The results of the test are given in Table 43 and the two-way analysis of variance follows in Table 44.

Table 43

Results of the observational pre-test

Raw mean scores on the observational pre-test according to allocated teaching group				
	Open-ended	Partial-direction	Check-list	
Year P	$\bar{x} = 14.05$ S.D. = 2.14 n = 18	$\bar{x} = 13.35$ S.D. = 2.38 n = 26	$\bar{x} = 15.00$ S.D. = 2.02 n = 24	$\bar{x} = 14.11$ S.D. = 2.19 n = 68
Year R	$\bar{x} = 14.38$ S.D. = 2.03 n = 18	$\bar{x} = 12.79$ S.D. = 2.08 n = 24	$\bar{x} = 14.04$ S.D. = 2.29 n = 21	$\bar{x} = 13.66$ S.D. = 2.13 n = 63
Year S	$\bar{x} = 13.47$ S.D. = 1.67 n = 19	$\bar{x} = 13.57$ S.D. = 1.78 n = 21	$\bar{x} = 14.11$ S.D. = 2.23 n = 18	$\bar{x} = 13.71$ S.D. = 1.88 n = 58
	$\bar{x} = 13.95$ S.D. = 1.96 n = 55	$\bar{x} = 13.22$ S.D. = 2.10 n = 71	$\bar{x} = 14.04$ S.D. = 2.17 n = 63	

n = 189

Overall mean = 13.83

Overall S.D. = 2.07

Table 44

Two-way analysis of variance. Pre-test scores with respect to allocated treatment mode and year group

Source of differences	SS	df	MS	F	P
Year groups	20	2	10	2.09	N.S. at 0.05
Allocated teaching group	28	2	14	2.92	N.S. at 0.05
Interaction	44	4	11	2.30	N.S. at 0.05
Within cells	861	180	4.79		
Total	953	188			

p(2/180) = 2.99 (at the p = 0.05) level

p(4/180) = 2.37 (at the p = 0.05) level

It will be noted that all the sources of variation produce non-significant results at the 0.05 level of significance; thus the sub-populations which were subsequently exposed to different teaching modes were initially equivalent in terms of observational attainment.

iv) General findings on equivalence of sub-populations

Neither on a global ability, nor on a science-based ability test was there any reason to assume non-equivalence between the treatment groups allocated to the three modes of teaching. This was very much confirmed by the observational pre-test. Therefore one can interpret subsequent findings resulting from post-tests and other measurements without concern for possible non-equivalence of the teaching sub-populations.

There is, however, a definite year-group trend in science ability, which may have some bearing on how well the pupils react to a learning experience, but as far as observational ability is concerned, no such year-trend variation exists, as can be seen from the data on page 145.

b) The results of the post-tests

It will be remembered that for each of the three year-groups involved in the study three sub-populations were subjected, respectively, to an open-ended, a partial-direction and a check-list approach as part of their learning experience. At the end of such learning experiences one type of post-test was administered, namely an open-ended one for year P, a check-list one for year R and a partial-direction one for year S.

The results are examined under three headings:

- i) results of positive scores made on the post-tests;
- ii) a pre-test/post-test analysis; and
- iii) a study of errors made on the post-tests.

i) The results of the positive scores made on the post-tests

The overall positive results scored according to the marking schemes previously described in section II of

Chapter 5 page 78 and Appendix B (vi) are given in Table 44, and a two-way analysis of variance examining observational attainment in relation to modes of testing and modes of teaching is given in Table 45.

Table 45

Results of the observational post-tests

Raw mean scores on the post-tests according to teaching mode				
	Open-ended	Partial-direction	Check-list	
Open-ended post-test Year P	$\bar{x} = 22.61$ S.D. = 2.26 n = 18	$\bar{x} = 22.86$ S.D. = 2.93 n = 26	$\bar{x} = 22.63$ S.D.=2.76 n = 24	$\bar{x} = 22.70$ S.D.=2.69 n = 68
Check-list post-test Year R	$\bar{x} = 25.22$ S.D. = 3.28 n = 18	$\bar{x} = 25.04$ S.D. = 4.65 n = 24	$\bar{x} = 26.28$ S.D.=2.95 n = 21	$\bar{x} = 25.50$ S.D.=3.76 n = 63
P-direction post-test Year S	$\bar{x} = 23.15$ S.D. = 2.08 n = 19	$\bar{x} = 22.38$ S.D. = 2.14 n = 21	$\bar{x} = 23.55$ S.D.=2.59 n = 18	$\bar{x} = 23.00$ S.D.=2.24 n = 58
	$\bar{x} = 23.65$ S.D. = 2.61 n = 55	$\bar{x} = 23.45$ S.D. = 3.28 n = 71	$\bar{x} = 24.11$ S.D.=2.76 n = 63	

Total possible score = 36
Total sample = 189

Table 46

Two-way anova based on the data in Table 45. Post-test scores with respect to testing and teaching modes

Source of variation	SS	df	MS	F	P
Testing mode	302	2	151	16.76	0.001
Teaching mode	15	2	7.5	0.832	N.S.
Interaction	19	4	4.25	0.471	N.S.
Within cells	1694	180	9.01		
Total	2030	188			

$p(2/188) = 6.91$ at the 0.001 level

Discussion of the results

The data reveals three main findings:

1. Observational attainment shown by pupils varies significantly with the modes of testing;
2. The observational attainment of the pupils does not seem to vary with the teaching mode used, and
3. There seems to be no significant interaction between teaching mode and testing mode.

The first of these findings is not surprising, in that it is a confirmation of the findings recorded in Chapter 5, page 92, according to which the observational attainment of pupils depends very significantly on the type and quantity of guidance given to them. The order, in this case as before, shows that the check-list performance is significantly better than the other two.

A consideration of the second finding, however, leads at first sight to some surprise, in that the apparent exposure to different modes of learning experiences employing the open-ended, partial-direction and check-list approaches respectively, does not appear to reflect itself in differential training in observation between the different groups.

The third finding is basically an extension of this argument. The idea may be adopted that any form of training provides, in the first instance, enhanced achievement related specifically to the type of training given, when a test is applied also related specifically to that form of training. If this is so then one might expect a pupil trained, for example, in a check-list procedure to perform better in a check-list oriented test. Likewise one might have expected pupils taught according to the open-ended mode to have performed more successfully on the open-ended variety of post-test. Clearly this is not so.

However, there is one minor caution to be expressed at this stage. Although the equivalence of the three treatment groups used in each year has been confirmed by the findings reported on pages 140-146 we have no direct evidence concerning the academic equivalence of the three different year groups. This equivalence has had to be assumed, though. A further point to be made concerns the possible influence of the other parts of the second year curriculum, particularly the other sciences, on the post-test results. It is obvious that a chemistry teaching programme cannot be carried out in isolation but is part of the pupils' total education. Therefore, changes in either teaching methods or the curriculum content within the other science subjects (the only subjects which used identical teaching groups), could have an influence on the post-test results of the present study. However it was ascertained that in neither biology nor physics, had there been any changes either in curriculum content or teaching method over the three year period of the research. Thus, the influence of these subjects was assumed to be stable throughout that period.

ii) The pre-test/post-test analysis

To examine the post-test situation further, bearing in mind that students would have had different initial individual levels of observational attainment, an analysis of the 'Gains' in observational performance in moving from the observational pre-test to the post-test was made. This gain is defined by equation:

$$\text{Gain} = \text{Raw Score (Post-test)} - \text{Raw Score (Pre-test)}$$

and the data are presented in Table 47 together with a two-way analysis of variance on the data which follows in Table 48.

Table 47 Gains shown by pupils in passing from pre-test to post-test

Gains shown according to teaching mode				
	Open-ended	Partial-direction	Check-list	
Open-ended test Year P	$\bar{x} = 8.33$ S.D. = 2.49 n = 18	$\bar{x} = 9.50$ S.D. = 3.14 n = 26	$\bar{x} = 7.58$ S.D. = 2.95 n = 24	$\bar{x} = 8.51$ S.D. = 2.96 n = 68
Check-list test Year R	$\bar{x} = 11.11$ S.D. = 3.99 n = 18	$\bar{x} = 12.25$ S.D. = 4.26 n = 24	$\bar{x} = 13.14$ S.D. = 3.37 n = 21	$\bar{x} = 12.22$ S.D. = 3.94 n = 63
Partial-direction test Year S	$\bar{x} = 9.68$ S.D. = 2.15 n = 19	$\bar{x} = 9.00$ S.D. = 2.53 n = 21	$\bar{x} = 9.59$ S.D. = 3.47 n = 18	$\bar{x} = 9.40$ S.D. = 2.73 n = 58
	$\bar{x} = 9.71$ S.D. = 2.90 n = 55	$\bar{x} = 10.28$ S.D. = 3.39 n = 71	$\bar{x} = 10.01$ S.D. = 3.29 n = 63	

Table 48 Two-way analysis of variance - 'Gains' with respect to teaching and testing modes

Source of variation	SS	df	MS	F	Significance
Testing mode	501	2	250.5	23.15	0.001
Teaching mode	28	2	14	1.29	N.S.
Interaction	41	4	10.25	0.95	N.S.
Within cells	1948	180	10.82		
Total	2518	188			

$$p(2/188) = 6.91 \text{ for the } 0.001 \text{ level}$$

Again, there seems to be no discernible trend in the attainment of the teaching groups, and in any case, the differences are not significant.

The only significant variation, as before, is that brought about by the testing procedure. Thus the conclusions to be drawn from the 'Gains' analysis are essentially the same as those arising from the post-test scores considered in isolation.

§ii) Errors made in the post-tests

As previously reported in Chapter 5, observational errors are basically of two types: errors of omission where pupils fail to report stimuli and illusory errors where pupils report 'observations' that have no factual basis. Again, as in the earlier chapter, there is little point in analysing omission errors since they closely reflect positive scores, but illusory errors warrant further investigation since they are not related, per se, to positive findings.

It will be remembered from the earlier chapter that although the check-list mode, applied in a testing situation, produced the highest level of observational attainment, it was also responsible for the highest illusory error levels. That is to say that the check-list mode, as used by those pupils, led to some degree of suggestibility on their part in relation to the 'detection' of spurious stimuli. The basic question to be asked now is whether the tendency of the check-list mode to produce illusory errors under test conditions is moderated by the previous training in observation given to those students.

The data relating to illusory errors is presented in Table 49; these data were analysed for significance, and the results of the analysis follow in Table 50. (In each case, the results may be compared with a total positive maximum of 36 stimuli on the post-test to give an impression of the order of magnitude of the illusory errors).

Table 49 Number of illusory errors made in the post-test (raw scores) according to teaching and testing modes

Number of raw mean illusory errors made according to teaching mode				
	Open-ended	Partial-direction	Check-list	
Open-ended post-test Year P	$\bar{x} = 1.79$ S.D. = 1.90 n = 19	$\bar{x} = 2.42$ S.D. = 2.34 n = 26	$\bar{x} = 2.42$ S.D. = 2.09 n = 24	$\bar{x} = 2.25$ S.D. = 2.15 n = 69
Check-list post-test Year R	$\bar{x} = 6.45$ S.D. = 4.05 n = 20	$\bar{x} = 7.92$ S.D. = 5.41 n = 25	$\bar{x} = 6.96$ S.D. = 3.35 n = 26	$\bar{x} = 7.15$ S.D. = 4.37 n = 71
Partial direction post-test Year S	$\bar{x} = 4.37$ S.D. = 1.95 n = 19	$\bar{x} = 3.05$ S.D. = 1.75 n = 20	$\bar{x} = 2.21$ S.D. = 1.14 n = 19	$\bar{x} = 3.21$ S.D. = 1.64 n = 58
	$\bar{x} = 4.24$ S.D. = 2.76 n = 58	$\bar{x} = 4.54$ S.D. = 3.31 n = 71	$\bar{x} = 4.07$ S.D. = 2.35 n = 69	

Table 50 Two-way analysis of variance, illusory errors with respect to teaching and testing modes

Source of variation	SS	df	MS	F	P
Testing mode	938.97	2	469.49	48.55	0.001
Teaching mode	7.67	2	3.84	0.397	N.S.
Interaction	68.36	4	17.09	1.78	N.S.
Within cells	1828.00	189	9.67		
Total	2843	197			

$p(4/189) = 2.37$ at the 0.05 level
 $p(2/189) = 6.91$ at the 0.001 level

The data once again suggest that the check-list testing mode generates the highest level of illusory errors, and if one compares these figures with the data given in Chapter 5, Table 24, on page 101, it will be seen that, if anything, the number of illusory errors made by the younger pupils is slightly greater, but clearly not significantly so, than those made by the 4th year pupils participating in the earlier test.

Thus it is clear that the experience gained in the teaching programme has not moderated the tendency of the check-list students to make illusory errors.

c) Results in terms of the observational attainment levels reached in the course of learning experiences

i) Positive scores

It was hypothesised that the effect of exposure of students to different teaching schemes could manifest itself not only in terms of ultimate observational attainment, as measured by the post-test, which it clearly has not, as has been shown above, but it might show itself in the observational attainment levels achieved by pupils during the learning experiences. For this particular purpose, the pupils' observational attainment was closely monitored throughout the two terms of the course, during which they were exposed to different modes of task definition in connection with the observational aspect of the course work.

It will be remembered that the course design involved eight different syllabus sections (details were given on page 133). In the accompanying practical work, different observations had to be made in each section, the total numbers of which are given in Table 51.

Table 51 Number of possible observations in each syllabus section

Syllabus section	1	2	3	4	5/6	7/8	Total
Number of observations	8	16	16	36	24	27	127

(Section 5 was amalgamated with Section 6, and 7 with 8 because of the very small numbers of observations in sections 5 and 7)

Obviously these observations cannot be considered to be equivalent to one another, since they arose in different contexts and the chemical education purposes for which they were designed also differed. Neither were they, nor could they be,

designed with the information about thresholds in mind, given in Chapter 4, rather they represented typical laboratory situations in conventional second-year secondary school chemistry, in which the precise and accurate control over reagents necessary to achieve threshold value experimentation of a controlled type was an impossibility. (The section on thresholds showed clearly that the detection rate of a stimulus changed quite markedly with the intensity of that situation and to achieve stimulus equivalence then the stimulus intensities had to be carefully balanced). Therefore, because of the degree of stimulus non-equivalence present and the variability of the number of observations in each different syllabus section, the analysis of the course work was carried out on the total scores achieved by each teaching group within each year group. (For the sake of completeness, the complete raw scores of all ultimate sub-groups and syllabus sections are shown in Appendix c (iv), the maximum number of observations to be made, it will be remembered was 127.) Table 52 gives the relevant data.

Table 52 Course work observation positive scores

	Mean scores of teaching groups on the observation course work			
	Open-ended	Partial-direction	Check-list	
Year P	$\bar{x} = 75.4$ S.D. = 7.19 n = 20	$\bar{x} = 78.9$ S.D. = 5.16 n = 26	$\bar{x} = 90.9$ S.D. = 5.02 n = 26	$\bar{x} = 83.5$ S.D. = 5.87 n = 72
Year R	$\bar{x} = 78.0$ S.D. = 6.86 n = 22	$\bar{x} = 73.4$ S.D. = 8.27 n = 26	$\bar{x} = 83.3$ S.D. = 4.01 n = 25	$\bar{x} = 78.1$ S.D. = 6.18 n = 73
Year S	$\bar{x} = 69.6$ S.D. = 5.99 n = 18	$\bar{x} = 59.4$ S.D. = 5.45 n = 20	$\bar{x} = 67.9$ S.D. = 7.66 n = 18	$\bar{x} = 65.4$ S.D. = 6.93 n = 56
	$\bar{x} = 74.6$ S.D. = 6.97 n = 60	$\bar{x} = 71.5$ S.D. = 6.63 n = 72	$\bar{x} = 82.2$ S.D. = 5.41 n = 69	

A two-way analysis of variance was carried out on the data in Table 52, and the results follow in Table 53.

Table 53 Analysis of variance; Observational course work scores with respect to teaching group and year-group

Source of variation	SS	df	MS	F	P
Teaching group	4213	2	2106.5	51.25	-
Year Group	9437	2	4718.5	114.8	-
Interaction	1382	4	345.5	8.40	0.001
Within cells	7891	192	41.09		
Total	22923	200			

It will be seen from the data in the two tables that there is a very significant interaction between teaching groups and year groups. For example, whilst the total impression given by the teaching-group difference is that the check-list group produces the highest attainment level, it is clear that in the case of Year S this is not so, as the open-ended and check-list groups are equivalent. In years R and P, whilst the check-list groups are the superior ones, the relative positions of the other two modes are reversed. In neither case, however, are the open-ended/partial-direction differences significant at the 0.05 level, as shown by application of t-tests. To enquire further into the statistical significance of the differences brought about by year group and teaching group, bearing in mind a significant treatment year group interaction, we can calculate F values as follows:

$$\begin{aligned}
 F \text{ mode} &= \frac{MS \text{ (treatment)}}{MS \text{ (interaction)}} \\
 &= \frac{51.25}{8.40} = 6.76 \quad MS = \text{Sum of Mean Squares}
 \end{aligned}$$

$$\begin{aligned}
 F \text{ year} &= \frac{MS \text{ (year)}}{MS \text{ (interaction)}} \\
 &= \frac{14.8}{8.4} = 13.67
 \end{aligned}$$

In terms of the degree of freedom involved, 2 and 4, respectively, significance at the 0.01 level would be reached if $F = 18.00$ and at the 0.025 level if $F = 10.65$. Thus it is clear that the

contribution of the year group differences, significant at the 0.025 level, is more significant than that of the teaching mode. This bears out what was suspected earlier (page 146) that whilst the observational equivalence of the treatment groups, derived from the observational pre-test, had been clearly established, the differential academic nature of the year groups was something of an unknown factor and could determine their reaction to the treatment modes.

Thus in terms of the teaching programme, the check-list mode produces the highest attainment level of the three, but the difference between it and the other modes is not significant; however, we have a significant effect, at the 0.025 level of confidence brought about by the difference in the year groups.

This could not appear in the post-test results since each year group was tested by a different mode of testing procedure and this very strong effect (the testing mode) produces differences which were significant at the 0.001 level of confidence or better. However, in the procedure used to assess the teaching observation programme, the treatment groups were assessed on a criterion-referenced basis, and thus each year group was assessed on its own merits. Therefore, for instance, the open-ended teaching groups of Years P, R and S were directly comparable in terms of the numbers of observations they made under the same conditions, as were the other two treatment groups. Under these conditions a year difference manifested itself reasonably strongly, i.e. somewhere between the 0.025 and 0.01 levels of confidence.

ii) Observational errors made in the course of the learning experience.

As in the previous sub-section, there is little point in analysing omission errors since they have a direct relationship to positive scores; therefore the intention is to concentrate as before on illusory errors.

Illusory errors made in the course work

Since illusory errors occurred in the post-test it might be expected that the previously noted pattern of such errors would appear in the course of the learning experiences. To investigate this an assessment was made not only of positive findings but of spurious recordings also. The results of this analysis are shown in Table 54, and Table 55 gives the results of a two-way analysis of variance performed on the data from Table 54.

Table 54 Illusory errors made during the course of the learning experiences

	Mean illusory errors according to teaching group			
	Open-ended	Partial-direction	Check-list	
Year P	$\bar{x} = 2.20$ S.D. = 1.56 n = 20	$\bar{x} = 0.85$ S.D. = 1.03 n = 26	$\bar{x} = 4.73$ S.D. = 1.67 n = 26	$\bar{x} = 2.63$ S.D. = 2.21 n = 72
Year R	$\bar{x} = 0.68$ S.D. = 1.02 n = 22	$\bar{x} = 1.50$ S.D. = 1.57 n = 26	$\bar{x} = 3.88$ S.D. = 2.64 n = 25	$\bar{x} = 2.07$ S.D. = 2.32 n = 73
Year S	$\bar{x} = 0.67$ S.D. = 0.82 n = 18	$\bar{x} = 1.20$ S.D. = 0.98 n = 20	$\bar{x} = 2.27$ S.D. = 2.07 n = 18	$\bar{x} = 1.38$ S.D. = 1.54 n = 56
	$\bar{x} = 1.18$ S.D. = 1.38 n = 60	$\bar{x} = 1.18$ S.D. = 1.27 n = 72	$\bar{x} = 3.78$ S.D. = 2.37 n = 69	

Table 55 Two-way analysis of variance teaching groups considered against year group

Source of variance	SS	df	MS	F	P
Year group	49.23	2	24.62	9.08	-
Treatment group	306.50	2	153.25	56.55	-
Interaction	51.73	4	12.93	4.77	.01
Within cells	520.43	192	2.71		
Total	927.89	200			

Again we have a significant interaction effect, and the calculated F values for teaching group and year group differences are 11.86 and 1.90 respectively, where the $F(2/4)$ value = 10.65 at the 0.025 level.

This gives a situation in which the effect caused by the treatment group is significant at the 0.025 level, with the check-list mode producing the highest number of illusory errors, but it must be noted that the actual number of errors produced is very small indeed. In the testing situation, something like 7 errors were made on average by check-list pupils over a period of approximately an hour; but in the entire period of the teaching programme, i.e., two terms, the error mean average was about 4. Thus, although we have a significant difference between the treatment groups, the actual numbers of errors considered over the time in which they were made are virtually negligible.

In the teaching situation there was little pressure on pupils to make observations which had no factual basis, whereas it may be hypothesised that in the testing situation, carried out under examination conditions, there is a natural tendency to make sure that nothing is missed; hence this may be a possible reason for the difference noticed in the illusory error rate in the two different situations,

Summary of the chapter

This part of the study set out to investigate the training effect that exposure to teaching schemes might have on the subsequent observational attainment levels of pupils. These teaching schemes were based on a normal second-year chemistry course of two terms duration but were designed so that one corresponded to an open-ended approach, the second utilised a

partial-direction and the third was followed along a check-list approach.

The population was investigated for equivalence by three tests, the AH4 test of general intelligence, the 'Bristol' test of scientific achievement and an observational pre-test. The latter showed there to be no significant differences between any of the year groups, the experiment being conducted with three successive years in the same school, or with treatment groups. Whilst there were no significant differences at the 0.05 level or better between the general intelligence levels of either year groups or treatment groups, there was a significant difference established between the year groups in terms of scientific achievement levels.

However, when the students had been exposed to the teaching programmes and tested again in terms of observational attainment by means of a standardised observational post-test, it was observed that although there were significant differences in observational attainment brought about the mode of testing used, the mode of teaching did not have a significant effect. (Each year group was divided into three and each third submitted to one of the three teaching modes, but the testing differed according to the year group). The first year (P) was tested by an open-ended procedure, the second (R) by a check-list mode and the third (S) by a partial-direction approach. No significant interactions were discovered between teaching mode and testing-mode. All three groups made illusory errors in the post-test and the frequency of these made by the check-list tested students, which were significantly higher than the other two, did not seem to be moderated by having had exposure to a check-list form of teaching.

All year and treatment groups were also continually assessed for observational attainment during the course of the teaching programme. The results of this assessment showed a significant interaction between the year group and the teaching procedure used. Whilst the effect of the training procedures did not reach significance levels, the year group effect was significant, albeit at the 0.025 level. Work earlier reported in Chapter 5 stressed that there was no relationship between chemical knowledge and observational attainment; thus it seems likely that the 'Year' effect is connected with the ways that the different pupils react to the teaching schemes.

The frequency of illusory errors made during the teaching scheme was far lower than in the case of the testing situations, with again the check-list mode being most prone to errors of this type.

CHAPTER 7 THE PROBLEM-SOLVING STUDY

Introduction

The work reported so far in the thesis has dealt almost exclusively with the observational phase of practical work, but, as was pointed out in Chapter 1, observation is not an end in itself in scientific investigations, but a means to an end. This end is that observational information is transformed into hypotheses and conclusions. This is essentially a problem-solving activity in which observational data arrived at during the observational phase serve as the basis for the interpretational activity.

Whilst success (or failure) in such interpretational activities must depend to a large extent on the student's intellectual, i.e. problem solving, skill, another factor of importance must be the quality of the observational data which are to be interpreted. As has been firmly established by the studies reported so far in this thesis, observational information derived by students in the laboratory is liable to contain errors. Thus, the important question arises how such errors affect the interpretability of observational data sets.

No indication could be found in the literature of any previous research into the ways in which students transform laboratory-based observations into inferences and conclusions, and how they cope with situations where such observations are either incomplete or contain erroneous or excessive information.

In view of this it was decided, therefore, to carry out, as part of this study, an initial exploration of the relationship between the quality of observational attainment and students' subsequent interpretations of observation.

The relationship between the observational and the interpretational phases merits closer examination from a theoretical point of view. It has already been established in Chapters 5 and 6 of the thesis that observations are subject to two types of error, viz. errors of omission and illusory errors. Such errors are likely to cause incomplete or erroneous interpretations and this will be investigated below. However, another possible factor influencing success in interpretational situations is the actual use that the student makes of observational information at his disposal. For example, if a set of observations is not fully used by the student, the interpretation may well be of a lower quality (or less comprehensive) than it would have been had all the available information been considered. This leads us to suggest that in an examination of the relationship between observational data and the interpretation based upon them, attention must be paid to i) the quality (i.e. correctness) of the data themselves, and ii) the use made of these data.

II

A theoretical basis for the study

a) The classification of observational data sets

In normal chemistry practice, interpretation is not usually based on single observations but on sets of observations which may be referred to as "observational data sets". For this reason, the observational exercises used in the studies described in Chapters 4 and 5 cannot yield the kind of information which could be of value in this part of the work: essentially these exercises produced "single observations" rather than observational data sets. For the development of observational data sets suitable for this part of the study, a new typology was evolved reflecting different characteristics of the data sets. The key

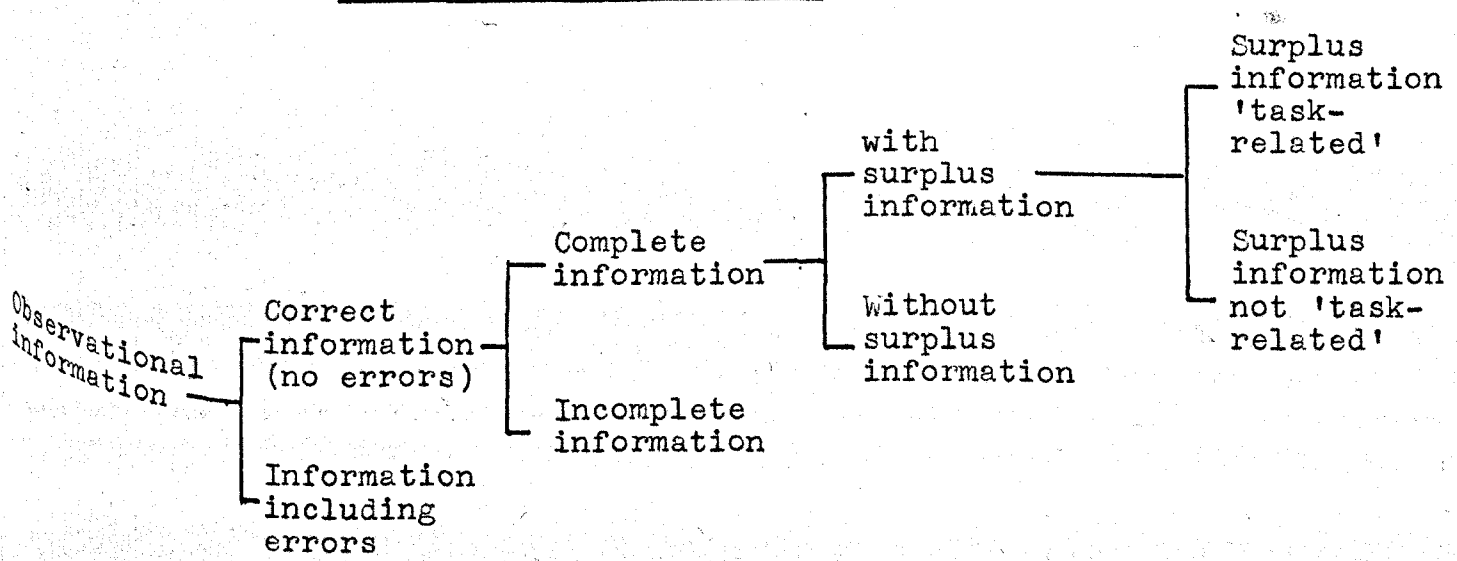
questions, on the basis of which data sets may be classified, are as follows:

- i) Is the information given in the data set entirely correct or does it contain erroneous details?
- ii) Does the data set provide adequate information for the solution of a specified problem or is it incomplete and will not allow for a full and unambiguous solution?
- iii) Does the data set contain information surplus to the accomplishment of the task? If so, is this surplus information related to the problem, or is it totally unrelated to it?

Each question may be answered in dichotomous terms, and on this basis the quality of the data sets may be analysed and classified as shown in Figure 13. This, it should be pointed out, summarises all possible types of data set, but only for sets containing no erroneous information. Data sets containing erroneous information are considered further in the next sub-section.

It must be noted that the characteristics of observational data sets cannot be assessed without reference to the particular problem-solving (interpretational) task to be solved by means of the data. Thus, the question of whether the information supplied contains, for example, surplus information, can only be assessed by reference to the task which is set.

Figure 13 A typology of observational data sets for use in interpretational tasks



b) The effects of the characteristics of data sets on interpretational achievement

i) Data sets containing erroneous information

This information corresponds to that produced as a result of the illusory errors referred to in Chapters 5 and 6, where students 'observe' phenomenon that have no factual basis. This type of information immediately raises problems of interpretability. If the erroneous information is a separate independent statement which is neither supportive of, nor conflicting with, other items of information presented in the data set; then under these circumstances the interpretation will inevitably result in an error. The other possibility is that erroneous information relevant to the problem conflicts with other information presented in the data set. Under these circumstances the student cannot resolve the conflict, even if he recognises it, unless he judges the relative "correctness" of the conflicting stimuli. Thus he has no rational basis for the interpretation. As will be stated, in the actual design of the study, sets including errors of both types were specifically excluded and thus the further discussion concentrates on the interpretation of correct data. (The term student is used in this part of the study rather than pupil since, as will be shown later, sixth formers are involved).

Examination of Figure 13 shows correct data can either be adequate for completion of the task or inadequate, i.e. incomplete.

ii) Incomplete data sets

These are situations in which errors of the omission type have been included and the information supplied is insufficient for the successful accomplishment of the task (unless, of course, the student makes unwarranted assumptions, or even guesses, as part of his interpretational procedure to compensate for missing information).

iii) Complete data sets

These are capable of being fully and correctly

interpreted, but it will be noted from Figure 13 that this type embraces not only situations where the information supplied is exactly what is required for the accomplishment of the interpretational task; but also situations where surplus information is also supplied. A particular point of interest concerns the use of excessive information by the student, i.e. information which is in itself not required for the solution of the problem. Two types of excessive information may be identified: task-related information (which may perhaps be helpful to the student) and task-unrelated information (which may act as a distractor).

c) The characteristics of laboratory-based information

A range of further questions may now be formulated concerning student behaviour in interpretational tasks based on observational information which concern not so much the quality of observational data sets themselves, but relate more to the nature of the observational information which arises from laboratory work in chemistry. As has been already stated above, such information is not generally obtained from individual, unrelated observations, but results from a sequence of tests which progress from "preliminary" tests to specific "confirmatory" tests. The "quality" of the information which can be derived from the two types of test differs significantly as will be discussed now.

i) Preliminary tests

These do not allow an unambiguous identification of a substance, but point to, or limit, the range of possibilities within which the identity of the substance can be found. In the light of the results of preliminary tests, further "confirmatory" tests are normally applied to establish the actual identity of a material or substance. Observations resulting from preliminary

tests may be positive or negative in terms of actual observations made, and may allow the presence or absence of substances to be inferred.

ii) Confirmatory tests

Whereas preliminary tests are mainly used to indicate ranges of possibilities, confirmatory tests are often quite specific and can on occasions be unique. Usually, however, the two types of tests are complementary in the sense that a limited range of possibilities has first to be established by preliminary testing before confirmatory tests can be used and acquire their confirmatory qualities. A number of questions arise concerning the interpretation of information derived from preliminary tests and from confirmatory tests, respectively.

These are as follows:

- 1) Do students recognise the quality of information derived from "preliminary" and "confirmatory" tests respectively. If so, is this reflected in the interpretation of such information?
- 2) Do students use a confirmatory test to its fullest extent or do they use only part of the information thus making the test less specific and less useful than it really is?
- 3) Do students, when presented with a sequence of tests ranging from preliminary to confirmatory tests, carry forward information in a systematic way? (If so, this strategy may be likened to Bruner's technique described by Bruner et al (1956) as "successive scanning". If, in contrast, individual pieces of information are held separately and unrelated from the others and considered only when all tests have been examined, this could be said to resemble Bruner's "simultaneous scanning" strategy).

A further question which may be asked here, although it does not relate directly to the quality of the observational

data, nor to the use to which they are put, is whether the habitual use of certain tests for particular purposes leads students to interpret such tests only in the narrow confines of these purposes, thereby ignoring other, wider, possibilities of interpretation. For example, tests involving barium chloride solution are generally used for establishing the presence of sulphate (IV) or sulphate (VI) ions depending on the pH of the solution, but could be indicative of a wider range of substances under different experimental conditions. It may be that the latter possibilities are not readily acknowledged by students in their interpretational work as the result of some "cognitive restriction". The foregoing questions concerning the relationship between observational attainment and interpretational performance are of major significance for chemical education, especially in relation to teaching and learning in the laboratory. For this reason, the part of the study described here represents a fully justifiable extension of the work into observational behaviour described in the previous chapter.

III The methodology of the investigation

In developing this part of the research, the author was very conscious of breaking new and unfamiliar (to him) territory. Whilst on the basis of the foregoing theoretical considerations, a sound set of research questions could be identified, issues concerning the methodology and strategy for an empirical investigation required further and separate consideration. Some of these issues are discussed in the following paragraphs.

The main issue in this part of the study is not whether students can interpret observational information, but how they do so and what strategies they adopt in this context. This calls for an investigative technique which allows students' thought processes to be "unfolded" in the course of attending

to interpretative tasks based on observational data sets.

The use of "in-depth" protocols would seem to fulfil the requirements stated above. This is certainly endorsed by Taylor (1966), who stated that "thinking aloud is a method most commonly agreed upon as the most valid means available today for collecting data on problem-solving". This method has been applied extensively to research in the problem-solving area in recent years, and the methodology adopted, based on student interviews and the recording of students' thoughts is well established and has been described extensively in the literature.

For instance, one can quote work by Webb (1975), who explored mathematical problem-solving; Lucas (1972), whose interest lay in the diagnostic implications of calculus teaching; Blake (1976), who enquired into the problem-solving processes as used by field-dependent and -independent students; Duncker (1945), who used the method to determine how and in what ways solutions of problems are attained from a "problem-environment". These and many other studies have been reviewed by Golding and McClintock (1979).

(The literature on problem solving studies in toto has multiplied to such an extent in recent years that to give even a brief account of the different methods and details of approaches to problem-solving studies is beyond the scope of this study).

It has to be recognised that the "in-depth" protocol approach allows only a relatively small number of students to be studied. The reason for this is the time-consuming nature of the technique. A consequence of this is that, the emphasis must be on gaining insight into students' problem-solving behaviour, rather than on obtaining information that can be

evaluated by means of the customary statistical techniques. The information obtained is thus both illuminative and diagnostic, rather than characterising problem-solving behaviour in terms of relative quantitative importance.

IV The scope of the investigation and experimental design

As was previously discussed in Chapter 3, it was decided to base this part of the investigation on observational information provided to students by the author, rather than on data derived by them from their own laboratory work. In this way the examination of how students coped in problem-solving situations when faced with different data sets could be related to "standardised" types of data set. These represented:

i) Complete data, i.e., data which supplied enough information for the complete and adequate solution of the task specified. This could include both positive and negative instances. In the case of a positive inference, this would mean that the performance of a test brings about a positive sighting from which an inference could be made; whereas a negative instance is one where the absence of a positive sighting can still be interpreted in that certain possibilities must be absent;

ii) Missing data, i.e., data which did not allow for a complete and unambiguous solution of the task;

iii) Excessive data, i.e., data which supplied more information than was actually necessary for the complete solution of the task.

The presentation of problems involving erroneous data was decided against for the reason that the inclusion of such data would have placed students into a situation where logical judgements could not have been made, and where, therefore, the problem would have been insoluble. The exclusion of problems

involving "erroneous data" from the study does not mean that such problems are not actually encountered by pupils in their work. It merely means that to have done so as part of "presented" information would have created an entirely artificial situation.

In the design of the interpretational problems, it was felt essential to present data in a manner that resembled realistic laboratory practice as closely as possible. For this reason the exercises were based on the range of practical work specified for the Cambridge 'O'-Level Chemistry syllabus (1980). This lists a number of inorganic ions whose reactions are to be studied. These are:

Cations: Ammonium
 Calcium
 Copper (II)
 Iron (II)
 Iron (III)
 Lead
 Zinc

Anions: Carbonate
 Chloride
 Nitrate (V) (Nitrate)
 Sulphide
 Sulphate (IV) (Sulphite)
 Sulphate (VI) (Sulphate)

Altogether 4 problems were developed, which are described and analysed in the next sub-section. The information as provided to students is in Appendix D (i). Each problem required students to identify the ions present in sets of mixtures of inorganic salts from the information provided. The information given embraced instances of "adequate data" representation, of "missing data", of "excessive data" and of "apparently conflicting data". In addition, a practice exercise (Problem no. 1) was devised and subsequently included in the test battery to give students familiarity with the mechanics of the recording procedure and practice in handling observational data in an interpretative manner.

a) The interpretation exercises described

i) A "complete data" instance - Problem 2

This exercise gave the results of a series of tests performed on a mixture of iron(II) sulphate (VI) and ammonium sulphate (VI). It should be made clear that the main point of interest in this and the other problems was not the derivation of a complete identification of all the ions present in the mixture, but to discover how students dealt with a specific section of the problem, which, in this case, corresponded to the "adequate data" type and enabled particular ion/ions to be identified clearly and unambiguously.

In this problem the students were given adequate information to enable them to deduce the presence of iron (II) ions, contaminated by some iron (III).

Three preliminary tests were specified (appearance, solubility in water and action of heat on the solid) which pointed to the presence of copper or iron in the mixture. Then two tests of the confirmatory type (action of dilute sodium hydroxide on an aqueous solution of the salt and the action of potassium hexacyanoferrate (II), again on an aqueous solution of the salt) enabled the students to decide unambiguously that iron (II) ions, with some iron (III) ions were present.

ii) A "missing data" situation - Problem 3

This gave the results of tests performed on a mixture of copper sulphate (VI) and copper carbonate, and the main point of interest was how students coped with the task of identifying the cation. Only preliminary tests were supplied in this context, namely a description of its appearance, the action of water and the action of heat on the solid. Although these tests limited the field of possibilities to either iron or copper ions, no further rationalisation could be made

without making unjustified assumptions.

iii) An "apparently conflicting data" situation
- Problem 4

This gave the results of tests performed on a mixture of lead carbonate and lead nitrate, but in this problem the main item of interest was to examine how students coped with the results of two tests which when one was interpreted in a habitual manner could give rise to a conflict. The first of these tests (the action of dilute hydrochloric acid on the mixture) categorically excluded the sulphate (IV) ion, (a negative instance) but a further test (the action of barium chloride solution on an acid solution of the mixture) gave a white precipitate, soluble in hot acid. Thus the conflict would arise if the barium chloride test was interpreted, out of habit, as being a "sulphate(IV)" test.

Enough information was supplied in the rest of the problem to enable the students to resolve the conflict by realising that the presence of lead ions (established by a sodium hydroxide test and the action of heat on the solid) could give a precipitate with barium chloride, not of the "usual" barium sulphate(IV) but of lead chloride.

Thus students needed to recognise that either the dilute acid test or the barium chloride test could not be habitually interpreted if progress was to be made towards a correct resolution of the conflict.

iv) Excessive data-set situation - Problem 5

This exercise gave details of an analysis of a mixture of calcium chloride and sulphate(IV). Not only was enough data given to enable the cation to be identified unambiguously as calcium, but excessive data, some of which was relevant to the problem and some completely unrelated, was

also supplied.

Of this superfluous information, that which was totally unrelated tended to be of a "physical" type, in that it defined physical rather than chemical characteristics, e.g., the physical appearance of the mixture as a lumpy solid. The preliminary tests (appearance, solubility in water and the action of heat) enabled the range of possibilities to be reduced to either calcium or zinc and the confirmatory test (sodium hydroxide solution), enabled calcium to be identified unambiguously. Further "confirmatory" information was supplied of both positive and negative instance type which was relevant to the problem, but totally unnecessary, since an unambiguous solution should already have been reached prior to the consideration of this later information.

b) Analysis of the interpretational procedures

Attention is now directed to questions relating to the interpretation of the different types of data set. Some questions, it will be found, are of a general nature and apply to all situations, whereas others are specific to particular types of data set.

i) General questions applied to interpretation

It has been stated already that information can be supplied in the form of either preliminary or confirmatory tests, characteristics of these tests are defined on pages 165 and 166. Thus one basic question is to ask if students recognise the limits of the data provided, i.e., do they treat preliminary tests as those which only restrict the range of possibilities or do they try to extract more from them than is logically possible? On the other hand do they use confirmatory tests to their fullest extent?

A second general question relates to the overall use of

the different data items. Since the analysis procedures described in this section are essentially sequential, i.e., moving from preliminary tests to confirmatories, do students recognise the sequential order and work to what Bruner has called a "successive-scanning" strategy, or do they not recognise the order and treat the tests as completely separate entities, using what amounts to a "simultaneous-scanning" approach, or are both approaches combined to some extent?

Questions relating to specific data sets

The "adequate" data set situation is entirely covered by the questions posed above and thus needs no further consideration. There is a need, however, for additional examination of the other data set types, and the scope of this is now explored.

ii) "Missing" data sets

The particular problem containing the "missing" data situation (Problem 3) supplied no data of the confirmatory type to enable the preliminary information to be refined. Therefore an examination needs to be made of the ways in which students attempt to "compensate" for the missing information, if in fact any such attempts are made.

iii) "Conflicting" data sets

As was stated before on page 172, the additional questions to be posed in this situation relate to whether students rely on a habitual use of the analysis scheme in their interpretations, and if any conflict which may arise is a) recognised and b) resolved.

iv) "Excessive" data sets

Two main additional questions need to be asked here. First, how do pupils cope with the irrelevant "physical" information? Do they use it and possibly get

confused by it or do they recognise its uselessness? Second, how do students deal with the redundant (but relevant to the problem) confirmatory tests; do they recognise that although they are sound in the information they provide, they are nevertheless unnecessary?

Experimental details

a) The population involved

This consisted of 11 students (9 boys and 2 girls) in the first year of their sixth form course at Caistor Grammar School. All of them were studying chemistry to 'A'-Level following the Nuffield course and having done Nuffield 'O'-Level previously. This particular population was selected for the following reasons.

i) Since qualitative analysis of a systematic kind is not included to any marked degree in Nuffield 'O'-Level chemistry, it is likely that they would have had little experience of qualitative analysis, as such, and thus the problems were new to them.

ii) The actual technique of obtaining in-depth protocols required a greater maturity than could have been obtained from younger pupils. (This had been indicated by a small-scale attempt to use fifth year pupils as the problem-solving population. This resulted in hesitantly delivered monologues with long silences masking the thinking process). It was found that first year sixth formers were a more suitable group from the maturity aspect and they produced reasonably continuous and articulate deliveries when taping.

b) The administration of the investigation

Because of the nature of protocols the investigation had to be done on an individual (one-to-one) basis. Since no time could be found to do this in school-time, it took place

in students' homes with the agreement of parents. The chemical analysis scheme shown in Appendix D ii) was sent to students together with a written instruction sheet one week before the problem-solving session was due to be held, so that each student could have an opportunity to familiarise him or herself with the material contained in it. (The chemical analysis schemes were available for use during the problem-solving sessions and were used universally).

The author tried to ensure that all students were at ease and familiar with the objects of the exercise. The written instructions were discussed and Problem 1 (a "practice" problem) was worked through as an example. It was stressed during this taping and before the actual problem-solving session started, that a continuous monologue was essential and that all thoughts were to be expressed out loud.

There were no difficulties in getting the particular students to co-operate fully and the practice problem was therefore used:

- a) to obtain familiarity with the tape-recording process, and
- b) to give students confidence.

(The analysis scheme supplied, ensured that the chemical facts necessary for the problem-solving process were available, thus difference in chemical knowledge background could not be a factor contributing to differences in interpretive behaviour).

In each problem the nature of all the tests was shown with the pertinent observations being concealed. Starting from the first test, the observations were revealed one by one, until the student was in possession of all observations relevant to each problem. This procedure gave the students both a realistic initiation to the problem-solving situation and also a realistically simulated set of data. The need for such simulation to be realistic when acting as a pre-cursor to problem-solving

was stressed by McGuire (1976). The students were able to stop the tape at any time and replay what they had recorded so that undue memory strain was avoided. Exactly the same procedure was followed with the remaining problems after Problem 2 had been dealt with.

The tapes were transcribed verbatim and the transcripts are shown in Appendix D iii). (For the purposes of confidentiality the students are referred to by code letters).

Results and discussion

The basic question is to explore how students handle information presented to them for interpretative purposes. Certain key questions were posed in section III, (pages 174,175) and the protocols were examined in the light of these questions.

It will be remembered that some of these questions were general to all forms of data-set used in the test-problems and others were more specific to particular forms of data-set. Essentially the general questions were as follows:

- i) Do students recognise the limits of each data item presented and do they use the data to its limits?
- ii) Do students recognise the sequential nature of the data items and respond with a consecutive scanning approach or do they use the simultaneous scan, treating data items as completely separate entities?

(The more specific questions will be raised in connection with the problems to which they are appropriate).

a) Interpretation of the "adequate" data-set Problem 2

This concerned the identification of the iron (II) with some iron (III) ions and involved preliminary tests backed up by two confirmatory tests. Two of these were needed since the first, the sodium hydroxide test was reported as giving a dirty-

green precipitate. This could be interpreted as iron (II) (pale green) with some agent causing discolouration. The second test of a confirmatory nature, using potassium hexacyanoferrate (II) solution gave a medium blue precipitate which confirmed that the impurity was iron (III) since iron (II) and iron (III) would be the only combination of permitted ions to produce this effect. Therefore, in terms of the first question, relating to the extent of the use of individual data-items, one would expect to see the preliminary tests used only to open up possibilities and the confirmatory tests used to their fullest limits to arrive at the iron (II)/iron (III) combination.

i) Tests 1, 2 and 3

These preliminary tests, not allowing the identification of a specific ion but allowing the limitation of possibilities to the presence of three ions (Copper (II), Iron (II) and Iron (III)) were used by most of the students for just this purpose. Some of them, however, advanced firm conclusions on the basis of these tests. In doing so they clearly made assumptions which were not justifiable on the basis of the information provided.

Turning to the second of the general questions referring to relationships established by the students between data items, it was found that about half the group treated the tests as basically unrelated. Each item of information was treated as independent from the others rather than as endorsing previous findings and the sequential nature of the observational items was not recognised.

ii) Treatment of Tests 6 and 7 - confirmatory data

These enabled exact identification to be made. Again there was a tendency to treat the information as "new", but it was more prevalent than in the section reported above

in that the degree of linking confirmatory test information to that obtained from the preliminary tests was less than that shown in linking items of a "preliminary" nature. However, in one of the minority of instances, where students did carry forward preliminary information to the interpretation of the confirmatory tests; one student (N) having specifically and wrongly, inferred copper (II) ions to be present (on the basis of preliminary data) allowed this hypothesis to so dominate his interpretation of the confirmatory tests that he accepted the green precipitate (in Test 6) as being "confirmatory" evidence for copper (II) and ignored Test 7, as it "doesn't tell me much". This may be thought of as a situation in which the limitations of preliminary tests were not recognised and, hence, a confirmatory test was not used in an appropriate manner.

Among the remainder of the students, there was a strong tendency not to use the confirmatory tests to their fullest extent. Most students were content to state that iron (II) was present or simply iron (without a stated oxidation number) whilst only a small minority advanced logically to an iron (II) with some iron (III), inference.

b) Interpretation of data sets containing "missing" information - Problem 3

Situations involving "missing" information generally comprise tests of the "preliminary" kind. It was of interest to examine how students coped with these situations and also what assumptions, if any, they made in their interpretation to "compensate" for the missing information.

Test 1 - Appearance - turquoise powder.

Most students recognised in this instance that the observation did not allow a specific identification and appropriately opted for the "iron or copper" hypothesis. (The one exception in fact failed to use the information).

Test 2 - Substance when shaken with water gives an insoluble residue, whose colour was not stated and a blue solution.

Again, it was not possible to be specific about what was there, but it would be possible to hypothesise that two salts were present. However, a surprisingly large number of the students did not use this information to help with cation identification. Instead, they concentrated on exploring the information which told them a blue solution was obtained together with an insoluble residue. A minority of students assumed that the blue colour was indicative of copper (II) and one student eliminated iron on this evidence, totally disregarding the information that an insoluble residue with no specified colour existed. Because most students ignored this information item, no overt links were made between this and subsequent information in the problem.

Test 3 - Action of heat on the solid

Most of the students opted for a general "iron/copper" hypothesis and there was some linking of findings to those from Test 1. There was evidence, though, that some students treated the preliminary data in an unjustifiably specific way: in the present case, the assumption of copper ions being present was "justified" only in terms of the blue colour of copper sulphate(VI).

c) Interpretation of data sets containing "conflicting" information - Problem 4

Although the information given in this problem was entirely adequate for a correct solution, it was thought possible that a habitual mode of interpretation of one individual item (the "barium chloride" test) could generate a conflict in the students' mind. This is so because the test with dilute acid shows sulphate (IV) to be absent from the sample, whereas the barium chloride test, in its traditional interpretation, suggests that this ion is present. Thus, three

questions arise in connection with this problem:

- 1) Did students interpret the dilute acid test correctly and thereby, eliminate the presence of sulphate(IV)? (Test 1)
- 2) If so, how did they treat the results of the barium chloride test? (Test 2b).
- 3) If a conflict was generated, how was it resolved?

(Subsequent information allows any conflict generated to be resolved, at least potentially, in that Tests 2c and 3, when combined, show that lead (II) ions were present in the sample, and thus the precipitation with barium chloride solution was caused by the reaction between lead ions and chloride ions).

Results of Test 1 interpretation

Whereas most of the students correctly interpreted the limewater reaction (which was part of the test) some failed to take cognisance of the fact that potassium dichromate paper was not affected by the gas evolved when the solid was treated with dilute nitric acid. Thus, only those who did eliminate the sulphate (IV) ion were in a position to generate a potential conflict situation. Thus already we are seeing an "adequate" data situation converted to a "missing" one by some students. This therefore gives rise to a situation in which the barium chloride test can be interpreted (wrongly) in the habitual way without conflict arising.

Considering now only those students who recognised that the sulphate (IV) group was absent, two patterns emerge. These correspond to the "simultaneous scanning" and the "successive scanning" approach. The majority of the pupils simultaneously scanned, that is they went through the process of postulating sulphite (IV) on a habitual interpretation of the barium chloride test, then they compared the results with that of the nitric acid test and saw the conflict. One student (Q), however, used

a successive scanning technique and did not even consider that the barium chloride test could indicate sulphate (IV). (In his protocol he did not suggest what the barium chloride instigated precipitate was, even though he used the rest of the data to indicate the presence of lead ions).

Returning to the pupils who, by use of the "habitual" barium chloride test interpretation, allowed the conflict situation to develop; most, but not all of these, interpreted Tests 2c and 3 to postulate the presence of lead ions. In spite of this the conflict was not resolved. It would seem that although a connection was made by the majority of the students between the two sulphate(IV) related tests, the lead tests were treated as completely separate and not used to resolve the conflict.

d) "Excessive data" situation - Problem 5

In this problem there is a need not only to examine the general questions of how pupils treat individual data items, be they "preliminary" or "confirmatory"; and how they collate their information, but also, in this special situation, how they react to excessive data of

- i) the task-related and
- ii) the task-unrelated variety.

In this particular problem some irrelevant data was of the "physical" type, i.e., that which referred to physical characteristics or changes of state and was integrated into the "preliminary" tests and thus was in competition with relevant data for the students' attention. Therefore we need to examine if the irrelevant data had a specific distracting effect within the confines of each particular test item. The unrelated data of a chemical kind i.e., results of tests which could have no bearing on the issue and the related but excessive chemical data stood as tests in their own right and, thus were not in

this sense competitive for students' attention.

The specific task to be considered here was the identification of the calcium cation.

i) Treatment of preliminary information

When students examined the results of the appearance test they used the information to exclude the "coloured" possibilities (iron and copper) and the irrelevant "lumpiness" was almost totally ignored. However, when they came to Test 2 (action of water) much less use was made of the information than in all previous instances where preliminary information was concerned. Also, with respect to this test the irrelevant "endothermic change" was not only ignored but positively rejected as useless by some students. A similar pattern with regard to irrelevant information followed in Test 3, but more positive use was made of the white residue to indicate zinc, but, curiously, not calcium. There was no attempt whatsoever to link the items, or carry forward information.

ii) Treatment of confirmatory tests

Almost without exception the students identified calcium as present from Test 5 (sodium hydroxide test), however, as it will be seen when the remainder of the tests are examined, they all failed to realise the full implications of the test.

The only exception to this was one student (P) who, having used preliminary Test 3 in an over-restrictive way to "prove" zinc, interpreted the sodium hydroxide test, quite wrongly, as "confirming" his findings. This is a similar behaviour pattern to that shown by student N (page 180) on Problem 2 in that once a firm hypothesis is generated and carried forward, even if it is erroneous, it affects the judgement of students with respect to following information.

The response to the tests which followed (ammonium hydroxide)

(potassium hexacyanoferrate(II) and dilute sulphuric acid) clearly shows the reliance being placed on the simultaneous scanning method. Test 5, referred to above, not only proved calcium, it also eliminated all other possibilities, yet all students "eliminated" possibilities as a result of the ammonium hydroxide and potassium hexacyanoferrate(II) tests and "proved" calcium as a result of the dilute sulphuric acid test. Even the erroneous postulation of zinc by P was not corrected as a result of these tests, but both calcium and zinc were held as possibilities. However, a few of the students did overtly admit that the information which could be derived from the three tests referred to above did not add anything to their knowledge. In spite of this they still used it.

VII Conclusions

As was mentioned earlier in the chapter, the nature of this part of the study was exploratory in nature, i.e., there was no attempt made to seek quantifiable conclusions. Rather the object was to recognise patterns of problem-solving behaviour with respect to the interpretation of observational data. Some broad conclusions are now advanced summarising the findings made. These are of course of a qualitative nature.

a) It is evident from the results of this study that students frequently do not recognise the limits of interpretability of the observations presented to them. This is particularly pronounced in the way that the results of preliminary information are handled. As has already been pointed out, the results of preliminary tests do not allow a full and unambiguous interpretation to be made; yet students frequently went beyond these limits and interpreted the results of preliminary tests

with a greater degree of precision than was warranted.

Conversely, there was also evidence that, in the case of confirmatory tests, information resulting from them was not always interpreted in the fullest sense. A possible reason for this is that confirmatory tests are not considered in conjunction with preceding preliminary tests, but in isolation. This point is taken up in the next part.

b) A successful interpretation of data sets required that the various parts of the information supplied should be linked in the way indicated in the section above, i.e., once a preliminary test had been used to restrict the range of possibilities, then the confirmatory tests serve to point the students to an unambiguous solution. It is clear, however, from the results that this particular group of students made little attempt to carry forward the results of the interpretation of one data item to those following it. The prevalent tendency was to keep items separate and rely on a "simultaneous scanning" technique. This involved repetitive "confirmations" of the same findings. The minority of students who did carry forward information adopted the more efficient "successive scanning" approach.

There were occasions, however, where erroneous hunches arising from the incorrect use of preliminary test information were carried forward so strongly that students were caused to interpret "confirmatory" information falsely in an attempt to justify the original, incorrect, hypothesis. The fact that tentative ideas (hunches) serve to direct subsequent search activity was recognised by Wilson and Koran (1976), and it is evident from the results of this part of the study that this is so here, even if the original hunches were erroneous. However, this degree of "carry forward" was rare, most students did not

connect different items of information so strongly, if at all.

c) A further aspect of this inability to connect information items was seen where conflicts were generated in the minds of students by interpreting certain items of information in a narrow or habitual way. For instance, students who correctly eliminated the presence of a particular ion as the result of information from one test were in the habit of reinstating it as the result of a subsequent test which apparently "proved" it to be present. This is in accord with the findings of Bady (1976), who discovered that over half of the high school students in his sample used the incorrect "verification" hypothesis rather than the more correct "falsification" hypothesis. The latter means that if information from a test proves conclusively that a particular ion is absent from a sample, any subsequent test that "proves" that it is, must be re-interpreted in a different manner. It is evident that students created conflicts by interpreting certain data items in a narrow habitual manner, relying on the "traditional" information given in the analysis scheme.

d) In one of the problems, excessive information was supplied, and it was found that students tended to ignore either covertly, or, less frequently, overtly, data items which were not related to the analysis scheme supplied to them. This may have been because they recognised the intrinsic uselessness of the data in the interpretational process, but there is evidence to point to the hypothesis that the information was ignored simply because it did not correspond with the information on the analysis scheme. On the other hand, when students were presented with information that, although relevant to the issues of the problem, was completely superfluous, they inevitably considered this information and almost always used it, even though some of

them recognised that no further purpose was served in doing so.

The students who participated in this part of the study were, it will be remembered, unfamiliar with the type of qualitative analysis exercises which formed the basis of the problems. Therefore a knowledge of the ways in which these students attempt to solve the problems can have important implications for the teaching and learning of problem-solving skills not only in the area of qualitative analysis, but also in other situations where a similar logical sequence may be encountered.

CHAPTER 8 OVERALL CONCLUSIONS AND SUMMARY OF THE THESIS
TOGETHER WITH SUGGESTIONS FOR FURTHER RESEARCH

The study set out to examine three separate, but related problem areas concerned with observation and observational attainment in practical work in school chemistry, namely:

- i) an examination under carefully controlled conditions of the effect of different modes of task definition on the observational attainment of pupils (the task definition study)
- ii) whether the use of different modes of training in a school teaching situation leads to different levels of observational attainment;
- iii) an exploration, on a pilot scale, of the relationship between the quality and type of observational data possessed by students and their treatment in subsequent interpretational processes (the problem-solving study). An essential precursor to these investigations was a preliminary examination of observational threshold levels pertaining to stimuli encountered in normal school practical chemistry.

The general findings resulting from the various phases of the study may now be summarised as follows.

a) The study of observational thresholds

With respect to the study of observational thresholds, values of such thresholds (defined as the intensity of a given stimulus at which 50% of the population will detect

it) were determined for the following types of phenomenon:

- i) thermal changes;
- ii) precipitation changes;
- iii) the redissolution of precipitates;
- iv) the dissolution of added solids;
- v) colour changes;
- vi) effervescences; and
- vii) olfactory changes.

Details of these threshold values, together with appropriate threshold curves are given on pages 43-63 of Chapter 4.

Essentially, such values are specific to the type of observation made, and no general conclusions can be drawn from them.

Although threshold values appear to be stable for single observations, they are influenced by the simultaneous presence of other observational phenomena. The general finding is that threshold values for particular observations are raised by the presence of other phenomena, i.e., they require higher intensities to be created for a comparable level of detectability. Details of this aspect of the study are given on pages 63-71.

From an educational point of view, these findings are important for the following reason. It is often assumed by teachers that any observation which can be made by pupils will actually be made by them. This is so simply because the teacher knows that the observation is there to be made, but does not fully appreciate that the uninitiated learner has no such knowledge. Therefore failure to make observations is not necessarily the consequence of inadequate pupil attention, but can be the result of observations being presented at a level below threshold value or being interfered with by other influences.

In all the threshold experiments reported in Chapter 4, the attention of the pupils was directed to the appropriate stimulus(1) under review. For example, in the context of the measurement of detection thresholds for thermal stimuli (pages 43-47), pupils were instructed to look for thermal changes, and therefore were to some extent cued towards this observation. No attempt was made to identify threshold values in the absence of such cueing, as this would have been beyond the scope

of the present study. Nevertheless, from a theoretical point of view, it would be of interest to examine the effect of cueing on observational detection limits.

b) The task definition study

The task definition study, based on the standardised observation test described in Chapter 5, pages 77-81, showed that the mode of task definition used by pupils drawn from the fourth year of a secondary school chemistry course in an observational situation significantly affects the levels of observational attainment produced. In this respect, the check-list mode of task presentation was found to be superior to the open-ended and partial-direction modes, the results being statistically significant at the 0.001 level.

The overall observational attainment levels for the latter open-ended and partial-direction modes, were essentially similar to each other. Closer examination of this result revealed that compared with the open-ended mode, the partial-direction mode produced enhanced levels of observational attainment on the 'cued' observations, whilst depressing the attainment levels for the 'non-cued' observations (these findings were reported on pages 90-94).

It was also found that as the difficulty of an observational task (measured in terms of its task-complexity i.e., the total number of observational stimuli to be detected) increased, so the number of observations which were missed (omission errors) increased. This increase was not a gradual one, but rose suddenly at a task complexity value of 4. Although on an overall assessment, the check-list mode of task definition produced fewer omission errors than either of the other two modes (reflecting the positive score situation), this superiority was shown to be most marked in reactions having

high task-complexity values. For example, the data recorded in Table 28, page 109, shows that the difference in the mean number of omission errors made by pupils following the check-list mode of task definition as compared with the mean number of omission errors made by pupils following the open-ended mode was only 0.03 of an error for a reaction with task complexity value 3; compared with 1.00 errors in a reaction with task-complexity value 7. (It was not possible to carry out a direct comparison with the partial-direction scores because these were obtained as a result of some 'cued' and some 'non-cued' observations, whereas on the open-ended/check-list comparison, one compares entirely 'cued' observation with entirely 'non-cued' observations).

In terms of a second type of error which was made, illusory errors i.e., where pupils record observations which, in the circumstances, could not possibly have been made, it was found that the extent to which these were made was strongly influenced by the mode of task definition. In this context the check-list mode produced the highest number of illusory errors. However, as can be seen from the section of the thesis reported on pages 102-105, these errors were not distributed equally across all the perceptual fields encountered in the test, i.e., the visual, haptic and olfactory fields, but were found to exist predominantly in the haptic and olfactory fields. In addition no direct relationship was found to exist between the complexity of an observational task and the number of illusory errors made by pupils produced when that task was accomplished.

It was found that observational attainment levels were independent of levels of intellectual attainment in chemistry, as measured by a multiple-choice chemistry theory test, however,

the effect of the field-independency/-dependency cognitive style possessed by pupils was very significant on observational attainment. This particular cognitive style is an indication of an individual's ability to perceive information without interference from the context in which the information appears and represents a further dimension (of a more psychological kind) along which observational attainment may be explained and explored.

The results of this part of the study (pages 114-120) showed quite clearly, first in a pilot manner, then in a more extensive replication, that pupils who were field-independent produced significantly higher observational attainment levels than did pupils who were field-dependent. In addition, it was seen that although the effect of this cognitive style was seen across all modes of task definition, it was more pronounced in the *open-ended mode*, where no guidance was given to pupils, than in the other two in which pupils received cueing to some or all observations.

From an educational point of view, the findings from this section of the study have several important consequences. They demonstrate convincingly that a pupil's observational attainment is significantly affected by the mode of task definition employed by a teacher in a testing situation. The mode of task definition also influences the number of illusory errors which may be made. The nature of these errors, however, is dependent more on the perceptual field giving rise to them than on the modes of task definition used.

The overall attainment level (78%) obtained using the most efficient (from the point of view of positive scores) mode of task definition, the check-list mode, serves to remind one that observations are still being missed and therefore if, as

it has been suggested, these observations form the basis for subsequent interpretative work, this interpretation could very well be impaired.

c) The teaching study

Observational attainment, as was shown by the task definition study, differs for different conditions of task definition. In view of this, the question was posed as to whether teaching approaches based on the three modes of task definition would produce different observational outcomes. Several alternative hypotheses were put forward concerning the potential effectiveness of teaching approaches based on:

- a) an open-ended approach;
- b) a partial-direction approach; and
- c) a check-list approach.

These hypotheses are outlined on pages 125-126 of Chapter 6. For the purpose of exploring this matter, the teaching study was planned and carried out.

In order to investigate all the various hypotheses, a strategy was suggested (shown on Figure 12, page 128) that involved pupils in being allocated to one of the three teaching approaches. Subsequently these teaching groups were further sub-divided and tested by the three testing modes. Ideally, this would have required a population of approximately 270 pupils, but this was not available. Instead, as a necessary and unavoidable compromise, the research was carried out over a period of three academic years using successive second year secondary school populations drawn from the same school. Pupils in each of the three year groups (designated respectively P, R, and S by the school) were allocated to three treatment groups and taught by teaching methods based respectively on an open-ended approach, a partial-direction approach and a check-list approach. At the end of each teaching programme (occupying two

terms) the type of post test used however differed from year to year. The first year group (P) underwent an open-ended post-test the second (R) was tested by a check-list test and the final group (S) by the partial-direction test.

Prior to the commencement of the teaching schemes and bearing in mind the fact that different year groups were involved, the populations were examined for equivalence using tests of general intelligence (the AH4 tests); scientific achievement (the 'Bristol' test); and observation. These tests showed that the sub-populations allocated to the teaching groups were equivalent in all these respects. However, there was found to be a definite year group trend with respect to science ability which, as it was suggested on page 146, could well have a bearing on how pupils reacted to learning experiences (the trend was $S > R > P$).

The results of the teaching study both in terms of observational attainment levels obtained on the post-tests and also on a "Gains" analysis (Gain = score on observational post-test - score on observational pre-test), showed that although the mode of testing brought about significant differences in attainment levels, no such differences were found to exist as a result of the teaching method employed.

It was hypothesised (page 125) that any type of learning ought to lead to the acquisition of skills that are specific to that type of learning, and this might mean, for example, that pupils taught by the open-ended approach could be at an advantage when tested by an open-ended post-test, whereas pupils who had been taught by the other methods might be at a disadvantage on the open-ended test. The results show that this type of interaction (teaching method/testing method) did not occur.

With respect to the observational attainment levels reached in the observational course work (which was continuously assessed) the results showed that the teaching methods used did not produce statistically significant differences in attainment levels. However, there was a reasonably strong year-group influence on observational attainment in the course work exercises (of the order $P > R > S$) and a statistically significant interaction between teaching methods and year-groups (at the 0.001 level). In the first two year-groups (P and R), students taught by the check-list approach produced the highest observational attainment levels, but in the final year-group (S) the teaching group following the open-ended approach produced the highest attainment levels. That students can respond to different teaching methods in different ways is accepted by teachers and was illustrated in work reported by Crocker et al (1976) on a teaching study which examined the relative effectiveness of 'structured' and 'unstructured' methods of teaching. Their findings showed that whilst the majority of students preferred the 'structured' method and produced superior results when following that method, one group out of four tested produced better post-test results after having been taught by the 'unstructured' method.

When considering the broad results of the study it must be pointed out that the implementation of the study involved a compromise between pure research interests on one hand, and normal teaching requirements on the other. The nature of this compromise can be seen in two areas. One concerns the nature of the observations to be made in the course of the teaching programme and the reactions producing them, and the other concerns the conditions under which the study was carried out.

In a pure research project designed to investigate the effects of different teaching methods on observational attainment it is clearly necessary to use observations which are standardised and reproducible. Only then can viable comparisons be made between different treatment groups, be they year-groups or teaching-groups.

In this particular study, however, the choice of reactions, and hence of observations, was dictated by the requirements of the part of the syllabus covered in the study. This involved the use of some experiments whose observational outcomes could either not be standardised or only standardised with great difficulty. For example, there were several reactions which involved the use of heat and these are extremely difficult to standardise. Thus, whilst it was claimed with justification on page 156 that in the observational coursework the different groups were "directly comparable in terms of the number of observations to be made under the same conditions", it must be admitted that the 'non-standard' nature of some of the reactions might cause one to question the precise equivalence of some particular observations.

With respect to the conditions under which the teaching study was carried out, in a true research situation, examination conditions, with all that implies, need to be imposed in order to ensure that the observational attainment level reached by a student is directly attributable to him alone. Clearly this is impossible and undesirable in an actual teaching situation. In the study, students allocated to the different teaching groups worked in pairs (the normal laboratory practice in the school), and although they were specifically requested to record only their own personal observations it is reasonable to suppose that there was a risk that students could exchange

information and assist each other. Furthermore although the groups following the different teaching methods were kept apart from each other in the laboratory, they had the opportunity to exchange ideas and information after the lessons had ended and hence cause some 'blurring' of the teaching-group divisions.

From an educational point of view, however, accepting the validity of the strong year-group/teaching method interaction, it would be of interest to find out why pupils respond differently to a particular learning experience. Whitfield (1979), pointed out that it is important to match the learning styles of students with the teaching styles of their teachers and if this matching, in the observational phase, produces higher levels of observational attainment, then the subsequent, interpretative phase is likely to be put on a firmer basis.

d) The problem-solving study

The final, interpretational part of the study examined, in a pilot manner, the relationship between the types and quality of the observational data sets possessed by students and the subsequent use they made of them; in other words, it tried to link the observational and problem-solving phases.

The interpretational exercises were based on observational data sets that resembled realistic laboratory practice as closely as possible. Four problems based on qualitative inorganic analysis situations were constructed and given to the students (no direct laboratory work involving students was undertaken). Each problem required students to identify the ions present in sets of mixtures of inorganic salts.

These data sets represented a range of situations covering data sets with 'missing' information on one hand to those with 'excessive' information at the other; but no erroneous data was included in the problems. (Details of the data set

typology can be found on page 163, Figure 13).

The methodology adopted to explore the problem-solving behaviour involved the use of indepth tape recorded protocols. As a consequence of this the population used was a small one, comprising eleven grammar school sixth form students.

The findings, which were of a qualitative rather than a quantifiable nature, showed that the particular students involved did not always recognise the limits of interpretability of the data supplied to them. On a number of occasions, when given tests which were essentially 'preliminary' in nature, i.e., tests which by their very nature could only serve to limit the range of possibilities, but not point to specific ions; students used these tests to derive quite specific conclusions. On the other hand, when given information of the 'confirmatory' type, i.e., that which could point to a very specific conclusion, some of the students did not use this type of information to its fullest extent and thus failed to reach the specific conclusion.

All the data sets contained information given in a sequence of data items, but, on the whole, students did not connect these data items and use them in sequence, i.e., carrying forward inferences from one data item to the next. Instead they tended to treat each data item as a separate entity and then, when all the information had been assessed, tried to resolve the problem. This prevalent form of behaviour resembled that described by Bruner as 'simultaneous scanning'.

The students were all supplied with a particular form of an inorganic qualitative analysis scheme to assist them and it was found that the interpretations they made relied rather heavily on a rigid or habitual dependence on this scheme, rather than on a priori solutions based on chemical logic.

This type of dependence often led to the development of conflict situations in the students' minds, even though all the information supplied was correct. In addition, when students failed to acknowledge the limits of interpretability of data presented at an early stage in a problem and produced specific (and incorrect) hypotheses, these significantly affected their treatment of data items presented in the later stages of the problem. The latter stages, thus, tended to be interpreted strongly in the light of the early (incorrect) hypotheses and not with complete objectivity.

It was suggested briefly at the end of Chapter 7 that the educational implications of this phase of the study were important, and these implications are now considered.

The students who comprised the population used for this part of the research were, as far as inorganic qualitative analysis was concerned, almost completely inexperienced and therefore the problems were novel to them. However, they were intelligent and reasonably experienced in chemistry up to the first year of a Nuffield 'A'-Level course. It would seem then, that the attributes leading to efficient problem-solving in chemistry referred to above; i.e., the ability to recognise the limits of interpretability of data; the ability to recognise possible relationships which exist between different data items; and the necessity to keep an open mind when solving a problem, so that one is not constrained by a pre-determined or imposed mode of thought, are not automatically possessed by students, but may require to be taught and learned.

Therefore there would appear to be a need to develop methods of teaching problem-solving in terms of the issues raised above.

The research, as has been stated above, specifically

excluded erroneous data for the reasons given on pages 169-170, nevertheless, since students do make illusory observations, as was clearly shown both in the teaching and task definition studies, it would perhaps be advisable to investigate the interpretation of data sets containing erroneous information, an aspect which was beyond the scope of the present investigation. In addition, since this was in the way of being an exploratory study, a more detailed investigation into the analysis of protocols could be undertaken.

Finally, this thesis represents an attempt to look at observational attainment in chemistry in its various aspects. Clearly the study of observational attainment is a grossly neglected area, but it is vitally important within the framework of the practical domain. It has been shown, fairly convincingly as a result of this study, that not only does the nature of an observation affect observational attainment, for example, a visual stimulus tends to be easier to detect than a haptic one; but also the context in which the observation is made is highly relevant too, i.e., the mode of task definition affects observational attainment, as does the overall complexity of the observational situation.

In normal chemistry teaching observation is hardly ever an end in itself, but a means to an end, i.e., the interpretational process. In the final part of the thesis it has been shown that, even given observations of a particular quality, students differ in the ways they manipulate and handle the data. This, of course, takes one out of the observational area and into the problem-solving area, but the observational/interpretational link is there.

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APPENDICES

A P P E N D I C E S

Appendix A

Material used in the investigation into threshold levels in practical chemistry.

- i) The haptic study
- ii) The precipitation study
- iii) The redissolution of precipitates study
- iv) The dissolution of solids study
- v) The colour change study
- vi) The effervescence study
- vii) The olfactory study
- viii) Multi-stimuli study
constant thermal/variable effervescence
- ix) Multi-stimuli study
variable thermal/constant effervescence

Appendix B

Material used in the task definition study

- i) Colour vision test pro-forma
- ii) Chemistry multiple choice test material
- iii) Hidden figure test materials
- iv) Booklets used in the observation test
in chemistry
- v) Chemicals used in the test
- vi) Marking grid used in the assessment of
of the observation test
- vii) Analysis of multiple choice test items
- viii) Instructions to schools for the extended
'one-shot' case study

Appendix C

The Teaching study

- i) Observation pre-test, booklet and chemicals
used
- ii) Teaching scheme booklets (A, B, C) and
continuous assessment schedule
- iii) The 'Bristol' test (5A)
- iv) Raw scores of all sub-groups on
observational course-work

Appendix D

Material Associated with the Problem-Solving Study

- i) Problems used in the study
- ii) Copy of analysis scheme and instruction
sheet
- iii) Transcripts of the taped protocols

APPENDIX A

Material used in the investigation into Threshold levels in practical chemistry.

Pro-formas and chemicals used.

A(i) THE HAPTIC STUDY

Identity of Solutions used in Haptic Perception Study

Solution		Identity
A	3.0 M	Sodium hydroxide solution
B	2.0 M	" " "
C	1.5 M	" " "
D	0.5 M	" " "
E	0.2 M	" " "
V	1.5 M	Sulphuric acid solution
W	1.0 M	" " "
X	0.75M	" " "
Y	0.5 M	" " "
Z	0.4 M	" " "

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THE PERCEPTION OF THERMAL CHANGES

Instructions

You are supplied with solutions V, W, X, Y, Z, which are acids and A, B, C, D, E, which are alkalis. Take 1" depth of solution C and in a separate tube 1" depth of solution Y. Mix them in a third tube. Estimate what happens to the temperature of the solutions when they are mixed, by touch only. Record your findings by putting a cross in the appropriate column of the table below. Rinse out the test-tubes before starting the next experiment using the water supplied, not tap water. Try not to get water on your hands in case it reduces your sensitivity of touch. Dry your hands if you do.

Mixture	Warmer	No change	Cooler
CY			
DY			
CZ			
BW			
CX			
AV			
EZ			

A(ii) THE PRECIPITATION STUDY

Chemicals used were as follows:

Identity of Solutions used in the
Precipitation Study

Code	Identity
A	0.1 M Lead nitrate
B	1 M Sulphuric Acid
C	0.1 M Sulphuric Acid
D	0.1 M Calcium Chloride
E	0.25 M Sodium Hydroxide
F	Tap water - hard

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Test III

Sex

Perception of Precipitation

Introduction

You are supplied with six different solutions, which will be referred to by the code letters A to F inclusive.

These solutions may or may not react together to form precipitates when pairs are mixed.

Instructions

Mix together thoroughly 1" depth of Solution A with 1" depth of Solution D and note whether or not a precipitate is formed. Record your observation in the appropriate box in the Results table, using a cross.

When you have made your observation and recorded it, throw away the reaction product and repeat the sequence with the other pairs of reactants. Follow the order given please.

Results

Pair of Solutions	Precipitate produced	Precipitate absent
A plus D		
A plus C		
A plus E		
A plus B		
A plus F		
D plus E		

A(iii) REDISSOLUTION OF PRECIPITATES THRESHOLDS

Chemicals used in Precipitate Redissolution Study

Code Letter	Solution Description
A	0.125 M Zinc Sulphate
B	2 M Sodium hydroxide
C	0.9 M Sodium hydroxide
D	0.5 M Sodium Hydroxide
E	0.2M Sodium hydroxide
F	0.35 M Sodium hydroxide

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Test IV

Sex

Perception of the Re-dissolving of Precipitates

Introduction

In chemical reactions sometimes a precipitating reagent not only puts down a precipitate but is also capable of redissolving that precipitate if the reagent is added in excess.

Instructions

In the following tests you will be asked to add to 1" depth of Solution A separately, equal volumes (1" depth) of five reagents B to F inclusive, and report whether or not any precipitate which is formed re-dissolves. Add the precipitating agent slowly, shaking the test-tube as the reagent is added. To help you, the test-tube will be marked at 1" and 2" levels. It is imperative that the 1" depth of A and the 1" of the precipitating agent are strictly adhered to.

Record your observations by placing a cross in the appropriate Results box. When you have completed and recorded the result of each reaction throw away the reaction product before proceeding to the next pair. Do the reactions in the order indicated in the table.

Reagents	Ppt did dissolve	Ppt did not dissolve
A plus B		
A plus E		
A plus D		
A plus C		
A plus F		

Results

A(iv) THRESHOLDS FOR THE DISSOLUTION OF SOLIDS IN A SOLVENT

Identity of Solutions used in the Solubility Study

Solution	Conc. of Sodium Chloride
A	270 gm per litre
B	180 "
C	0 "
D	325 "
E	90 "
F	360 "

Wt of Solid S = 1.5 g.

Volume of solution used = 4 cm³.

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THE PERCEPTION OF SOLUBILITY OF A SOLID IN VARIOUS LIQUIDS

You are provided with equal volumes of five different liquids in test-tubes labelled A to E inclusive. You are also provided with five equal portions of solid S.

Add a portion of solid S to liquid A and let the solid settle. After you have made an estimate of the volume the undissolved solid occupies, shake the tube and its contents for about fifteen seconds. Let the contents settle again and estimate whether or not any of the solid has dissolved. Pour away the contents of the tube.

Repeat your experiments with liquids B to E inclusive and the other portions of solid S. Make your report in the table provided below by putting a tick in the appropriate answer box.

Liquid	Solid S dissolved	Solid S did not dissolve
A		
B		
C		
D		
E		

A(v) THRESHOLDS RELATING TO COLOUR CHANGES

Chemicals used in Colour Perception Tests

Code Letter	Identity
A	pH4 Buffer soln. with 40cm ³ Universal Indicator per litre
B	pH7 " "
C	pH9.2 " "
D	0.1 M Sodium Chromate solution
E	2 M Sulphuric acid
F	2 M Sodium hydroxide

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Test V

Sex

Perception of Colour Change

Introduction

A great many chemical changes involve changes in the colours of the reactants. In the reactions you are about to do, you are simply asked to report whether or not a particular reagent changes its colour. If you are known to be colour blind please put a cross in the box below and, if you can, state in which colour area your defect exists.

Colour blind

Colour area

Instructions

In experiments 1 to 6, add 1" depth of the Solution named as "Solution II" to 1" depth of the Solution denoted "Solution I". Record whether or not there is any change in the colour of "Solution I" by placing a cross in the appropriate response box. Finally, in experiment 7, add 1" depth of the solution denoted Solution II to 2" depth of Solution I. Again record your result.

Please throw away the reaction product each time before proceeding to the next reaction. Wash test-tubes with the distilled water provided and drain before using the tube again.

Reaction	Solution I	Solution II	Colour change	No colour change
1	1" A	1" F		
2	1" B	1" F		
3	1" A	1" B		
4	1" D	1" E		
5	1" C	1" F		
6	1" B	1" E		
7	2" B	1" A		

Results

A(vi) THRESHOLDS RELATING TO THE DETECTION OF EFFERVESCENCE

Chemicals used in the Effervescence Tests

Code	Identity
A	Sulphuric Acid 1 M
B	" 0.5 M
C	" 0.25 M
D	" 0.125 M
E	Sodium Carbonate 1 M
F	" 0.5 M
G	" 0.25 M
H	" 0.125 M
I	Water

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Test VI Perception of Effervescence

Sex

Introduction

In chemical reactions, often a gas is expelled in the form of small bubbles which we call an effervescence. In the reactions which follow, you are looking for the presence or absence of such an effervescence.

Instructions

Mix 1" depth of the first named solution with 1" depth of the second and report by means of a tick in the appropriate box whether or not you observed effervescence. Put Reagent (1) in the test tube first. When you have made each assessment, pour the reagents down the sink and proceed to the next pair.

Results

Reagent 1	Reagent 2	Effer- vescence	No Effer- vescence
A	I		
C	G		
D	H		
B	F		
A	E		

A(vii) PERCEPTION THRESHOLD RELATING TO THE DETECTION OF THE
DISAPPEARANCE OF A SMELL

Chemicals used:

Ammonium Hydroxide 2 M

Sulphuric acid 2 M

DETECTION OF A CHANGE IN SMELL

Place 4 cm³ of the Alkali solution in the test-tube (to the level marked).

Then carefully add Acid solution from the burette drop by drop.

Smell the tube after each addition has been shaken to mix.

Repeat the addition until you think the smell has disappeared. Record the burette reading in the space provided.

Fill the burette to the 0 cm³ mark and do the experiment again. Record your second result and find the average.

First Reading	=	cm ³
Second Reading	=	cm ³
Average	=	cm ³

A(viii) MULTI-STIMULI THRESHOLDS

Variable Effervescence : Constant Thermal Changes

Chemicals used in the study

Solution	Identity
A	M Sulphuric acid
D	Water
E	2 M Sodium hydroxide + M Sodium carbonate
F	2 M " " 0.5 M " "
G	2 M " " 0.25 M " "
H	2 M " " 0.125 M " "
I	2 M " "

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Test VII

Perception of Effervescence and Thermal Changes

Chemical reactions often involve two or more changes occurring simultaneously. In the reactions that you will be asked to perform there is the possibility that:

- a) Effervescence and/or
- b) Thermal changes may occur.

Instructions

Pour 1" depth of the first named solution into one test-tube and 1" depth of the second into another tube. When you have made your assessment of the temperature with your hand only, mix the liquids in your third tube. Try to estimate if:

- a) The temperature rises when the liquids are mixed, and
- b) If there is any effervescence.

Rinse out the tubes 2 and 3 and drain them before starting the next experiment. There is no need to do this to tube 1, which only contained A. Try not to get water on your hands in case it reduces your sensitivity of touch. Dry your hands if you do.

Record your results by placing ticks in the column.

Results

Soln. 1	Soln. 2	Warmer	Cooler	No change	Effervescence occurs
A	G				
A	I				
A	F				
A	H				
A	E				
A	D				

MULTI-STIMULI THRESHOLDS

Constant Effervescence - Variable Thermal Change

Chemicals used:

A	M Sulphuric acid
D	1.5 M Sulphuric acid
F	3 M Sodium hydroxide + 0.5 M Sodium carbonate
J	0.5 M Sodium hydroxide + Sodium carbonate
B	2 M Sodium hydroxide + 0.5 M Sodium carbonate
X	M Sodium hydroxide + 0.5 M Sodium carbonate
P	0.5 M Sodium hydroxide + 0.5 M Sodium carbonate

Then, for the lower region investigation, the following were used:

A	0.5 M Sulphuric acid
B	M Sodium hydroxide + 0.25 M Sodium carbonate
F	0.75 M Sodium hydroxide + 0.25 M Sodium carbonate
P	0.5 M Sodium hydroxide + 0.25 M Sodium carbonate
J	0.25 M Sodium carbonate
D	0.375 M Sulphuric acid

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Test VIII

Perception of Effervescence and Thermal Changes

Chemical reactions often involve two or more changes occurring simultaneously. In the reactions that you will be asked to perform there is the possibility that:

- a) Effervescence and/or
- b) Thermal changes may occur.

Instructions

Four 1" depth of the first named liquid into one test-tube and 1" depth of the second into another tube. When you have made your assessment of the temperature with your hand only, mix the liquids in the third tube. Try to estimate if:

- a) The temperature rises when the liquids are mixed, and
- b) If there is any effervescence.

Rinse out all tubes and drain them before starting the next experiment. Try not to get water on your hands in case it reduces your sensitivity to touch. Dry your hands if you do. Record your results by placing ticks in the columns.

Results

Soln. 1	Soln. 2	Warmer	Cooler	No change	Effervescence occurs
A	X				
A	J				
A	B				
A	P				
A	F				

APPENDIX B

Material used in the task definition study.

APPENDIX B i)

Colour vision test pro-forma

A MULTIPLE CHOICE TEST

IN

CHEMISTRY

UNIVERSITY OF KEELE,
Department of Education.

Completing the Answer Card

At the end of each question there are four possible responses from which you are required to select ONE. In each case select the alternative which in your view is the correct answer and then mark the answer card in the correct place.

Here is an example to help you:

Question 99

The county town of Lincolnshire is:

- A Market Rasen
- B Scunthorpe
- C Grimsby
- D Lincoln

The correct response to this question is D. The answer card should, therefore, be marked:

	A	B	C	D
99				X
100				

1. One property by which a pure substance may be identified is its
 - A. Colour
 - B. Smell
 - C. Volume
 - D. Melting point

2. When acetic acid is added to magnesium
 - A. No reaction takes place
 - B. Hydrogen is evolved
 - C. Magnesium oxide is formed
 - D. Carbon dioxide is formed.

3. In the preparation of oxygen from hydrogen peroxide, manganese dioxide is added because:
 - A. It prevents explosion
 - B. It acts as a catalyst
 - C. It gives out oxygen
 - D. It prevents wastage of reacting substances.

4. The substance which changes blue litmus red is
 - A. Vinegar
 - B. Milk of magnesia
 - C. Common salt
 - D. Soda water

5. Monoclinic sulphur and rhombic sulphur are allotropes
 - A. Because they differ only in their crystalline structure
 - B. Because one form could be converted to the other
 - C. Because they have a common melting point
 - D. None of the above reasons.

6. Balancing a chemical equation is based primarily on

- A. The law of combining volumes
- B. The law of reciprocal proportions
- C. The law of conservation of mass
- D. None of the above.

7. A gas which bleaches litmus is

- A. Hydrogen chloride
- B. Chlorine
- C. Ammonia
- D. Nitrogen.

8. The halogens occur in the Periodic Table in Group:

- A. I
- B. III
- C. IV
- D. VII

9. Which one of the following substances does not give oxygen when heated over a bunsen flame in a hard glass test tube?

- A. Sodium carbonate
- B. Potassium permanganate
- C. Potassium nitrate
- D. Red lead

10. A metal which does not show an increase in weight when heated in air is:

- A. Zinc
- B. Platinum wire
- C. Lead
- D. Mercury

11. When concentrated hydrochloric acid reacts with manganese dioxide, which one of the following does the reaction involve?
- Only oxidation
 - Only reduction
 - Both oxidation and reduction
 - Neither oxidation nor reduction.
12. Of the following changes the one that does NOT belong to the same group as the others is
- Powdering of blackboard chalk
 - Heating a little egg white
 - Striking a match
 - Adding acid to washing soda.
13. The yellow colour of a bunsen flame is due to:
- Supply of excess oxygen to the flame
 - Complete oxidation
 - Evolution of excess CO_2
 - Partial burning.
14. 6.02×10^{23} molecules of calcium carbonate are found in which of the following quantities of calcium carbonate?
- | | | |
|----|---------|-----------------|
| A. | 100 gm. | CaCO_3 |
| B. | 50 gm. | Ca = 40 |
| C. | 25 gm. | C = 12 |
| D. | 10 gm. | O = 16 |
15. When a liquid changes to a vapour, which one of the following may be considered to happen?
- Density of the material increases
 - The average distance between particles decreases
 - The average kinetic energy of the particles increases
 - The particles arrange in a regular pattern.

16. By Avogadro's Number is meant the number of:
- A. Atoms in 2 gm. of hydrogen
 - B. Molecules in 1 gm. of hydrogen
 - C. Atoms in 4 gm. of Deuterium
 - D. Atoms in a gram atom of the substance.
17. Which of the following processes is fundamentally different from the others?
- A. Rusting
 - B. Digestion
 - C. Fermentation
 - D. Burning
18. Which one of the following contains the largest number of gram-molecules?
- $H = 1, O = 16, S = 32$
- A. 1000 gm. of oxygen (O_2) molecules
 - B. 1000 gm. of sulphur vapour (S_8) molecules
 - C. 1000 gm. of sulphur dioxide (SO_2) molecules
 - D. 1000 gm. of hydrogen sulphide (H_2S) molecules.
19. When magnesium is burnt in steam:
- A. A mixture of oxygen and hydrogen forms
 - B. Oxygen forms
 - C. Hydrogen forms
 - D. No reaction occurs.
20. In general, a very active metal reacts with water to produce hydrogen and
- A. An acid
 - B. An oxide
 - C. A salt
 - D. A hydroxide.

21. A divalent metal M has Al as its less active neighbour in the activity series. Which of the following reactions probably will NOT take place?

- A. $M + H_2O = MO + H_2$
- B. $MO + H_2 = M + H_2O$
- C. $M + Cl_2 = MCl_2$
- D. $M + Pb^{2+} = M^{2+} + Pb$

22. Diamond and graphite differ because:

- A. Graphite is impure carbon
- B. The atoms in diamond are larger than those in graphite
- C. Carbon has a different number of bonds (valency) in the two forms
- D. The atoms of carbon are differently arranged in the two substances.

23. Which of the following concentrated acids will displace the other three from their salts?

- A. Hydrochloric acid
- B. Sulphuric acid
- C. Acetic acid
- D. Nitric acid.

24. The first substance to freeze out when atmospheric air is cooled is:

- A. Nitrogen
- B. Carbon dioxide
- C. Water vapour
- D. Oxygen.

25. The most suitable way to get pure sulphur from a mixture of sulphur and iron is to:

- A. Use a magnet
- B. Dissolve in water and filter the solution
- C. Blow on the mixture
- D. Dissolve in carbon disulphide and evaporate the resulting solution.

26. When the following oxides were heated with powdered carbon in a hot flame the one that behaved DIFFERENTLY from the others was:

- A. Zinc oxide
- B. Lead monoxide
- C. Calcium oxide
- D. Ferric oxide

27. Which one of the following may be considered as the best evidence for regarding the conversion of water to steam as a physical change?

- A. There is no difference in weight before and after the change
- B. The product is still the same chemical compound consisting of two elements combined in the same proportions
- C. No chemical change involves a change of state
- D. Water can be regained by cooling the steam.

28. Among the following substances, the one that would not normally be present in air is:

- A. Chlorine
- B. Carbon dioxide
- C. Water vapour
- D. Neon.

29. If a substance is made of particles which are in a regular pattern, it is most likely to be:

- A. A gas
- B. A liquid
- C. A crystalline solid
- D. A chemical compound.

30. Nitric acid is prepared in the laboratory by gently heating a mixture of two chemicals in a suitable apparatus. Is it -

- A. Sodium nitrate and conc. sulphuric acid
- B. Sodium nitrate and dil. sulphuric acid
- C. Sodium nitrate and conc. hydrochloric acid
- D. Sodium nitrate and dil. hydrochloric acid.

CHEMISTRY - THEORY

ANSWER SHEET

NAME:

SCHOOL:

FORM OR GROUP:

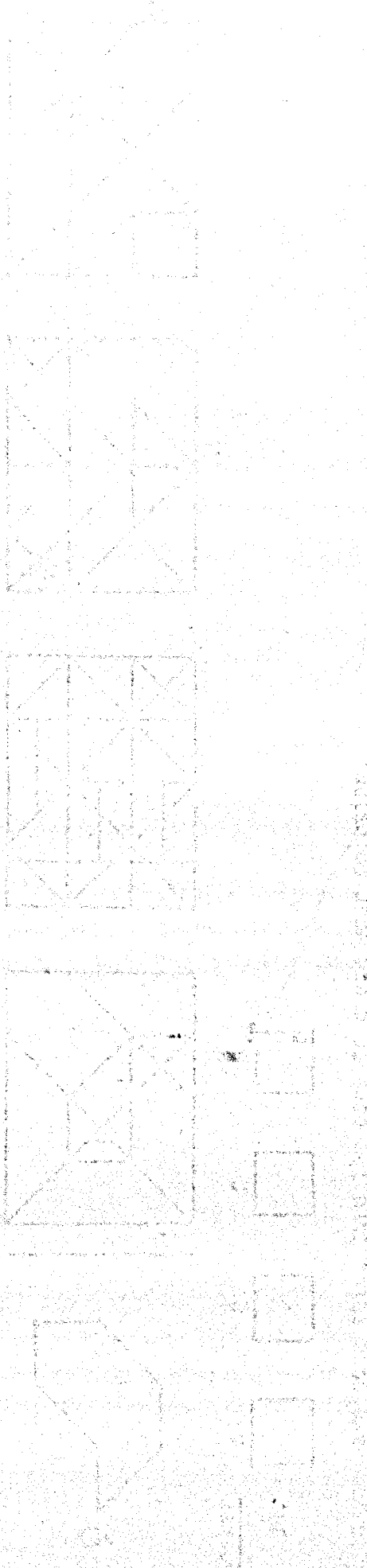
	A	B	C	D
1				
2				
3				
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10				
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12				
13				
14				
15				

	A	B	C	D
16				
17				
18				
19				
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26				
27				
28				
29				
30				

0	E	T

APPENDIX B iii)

Hidden figures test materials



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HIDDEN FIGURES TEST

This is a test of your ability to find a simple form when it is hidden within a complex figure.

Each item within this test consists of a simple form on the left followed by four complex figures on the right, labelled A, B, C, D. You should carefully examine each of these complex figures to find out whether or not the simple form is hidden within it. Then mark the box on your answer sheet accordingly. Record your answers as follows:

Put **X** in the appropriate box if the simple form is hidden in the complex figure.

Put **O** in the appropriate box if the simple form is NOT hidden in the complex figure.

If you are uncertain about whether or not a complex figure contains the simple form, do not mark the appropriate box.

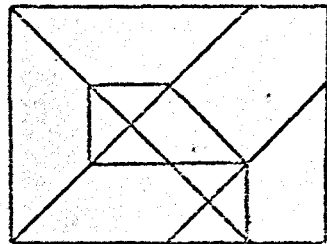
Note: The hidden form will always be the SAME SIZE and the SAME WAY ROUND as it is shown in the left hand column. It may appear in more than one of the four complex figures or in none of them.

Now try this example. When you have decided, put 'X' or 'O' in the boxes below.

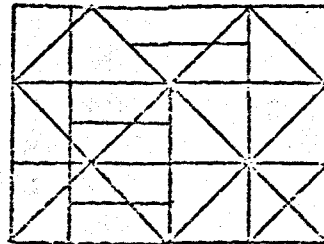
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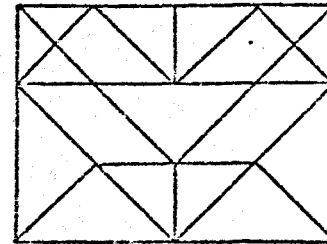
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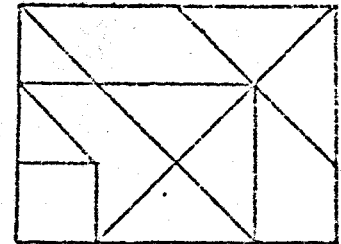
B



C



D



Answer

A

B

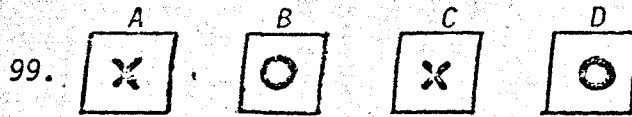
C

D

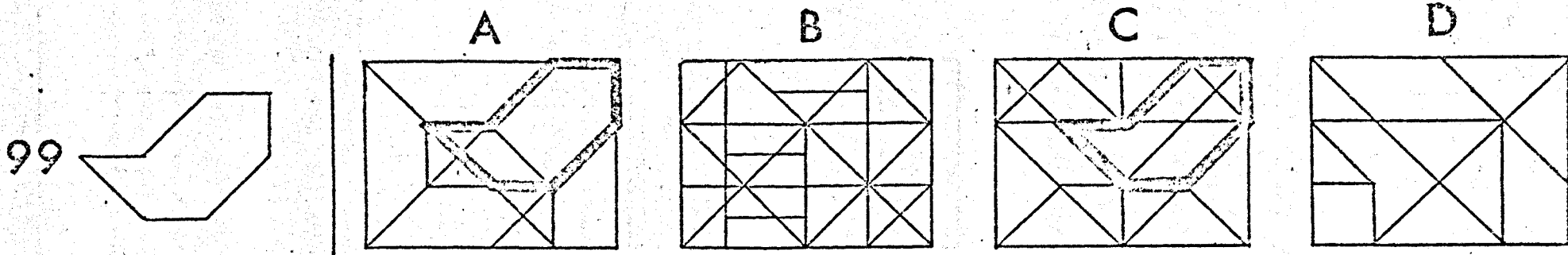
99.

When you have done this, turn the page to check your solution.

The correct answer is:



To show you the answer, the simple form has been traced over the lines of the complex figures within which it is hidden.



Work through the items quickly but carefully. It is advisable to work in pencil with a rubber available so that if you change your mind after you have marked your answer you can easily alter it. There are twelve items in the test and you have twelve minutes in which to do them.

REMEMBER the hidden form will always be the SAME SIZE and the SAME WAY ROUND as it is shown in the left hand column.

DO NOT TURN OVER UNTIL YOU ARE TOLD TO DO SO.

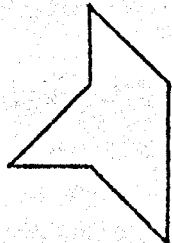
(Copyright 1976)



1



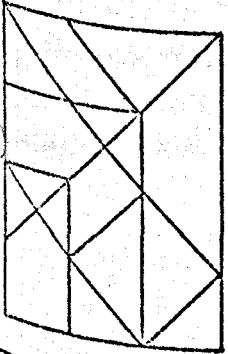
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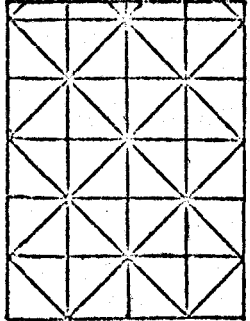
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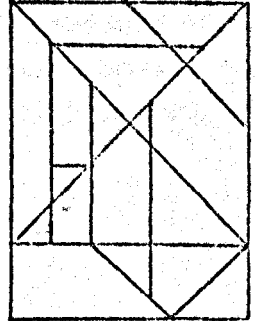
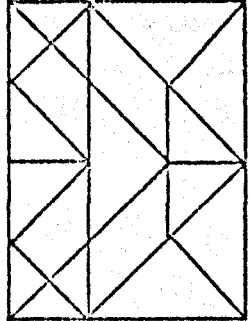
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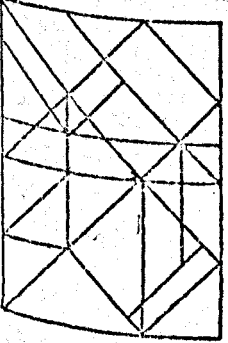
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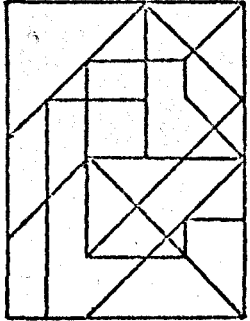
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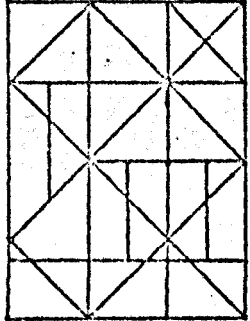
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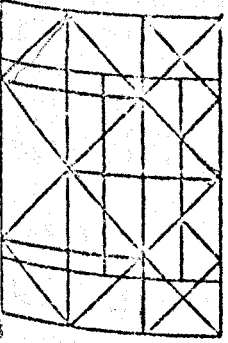
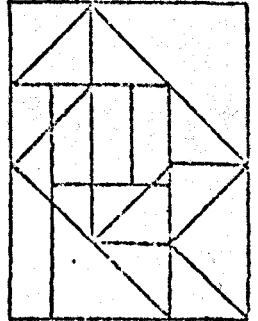
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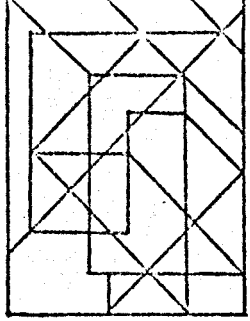
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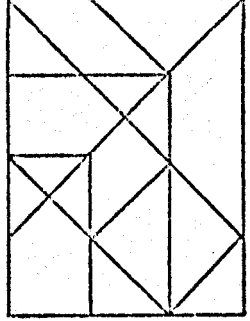
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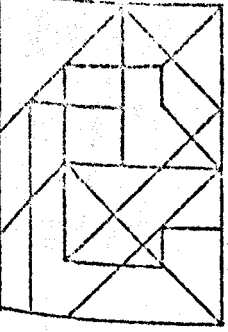
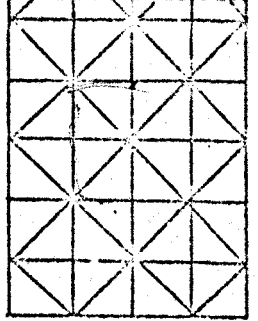
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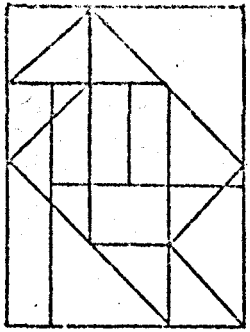
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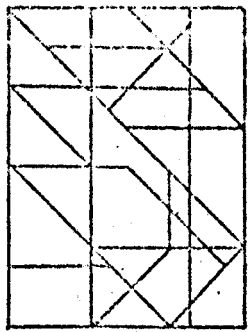
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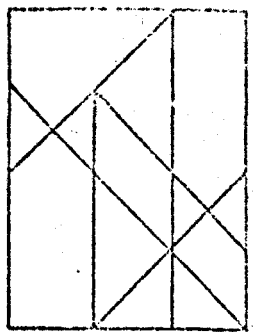
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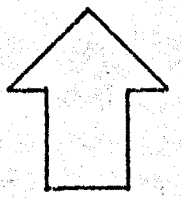


D



D





8



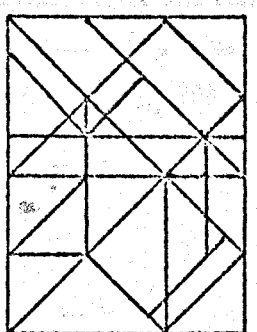
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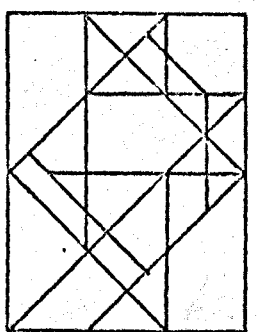
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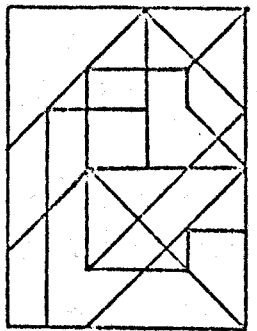
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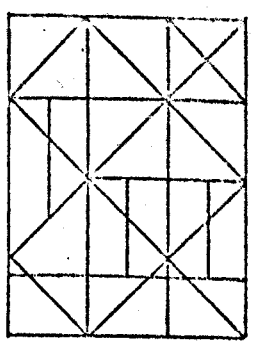
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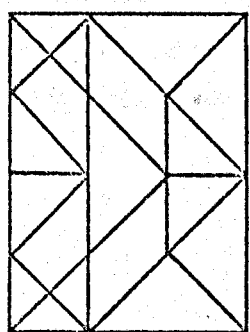
B



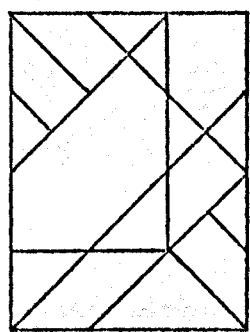
C



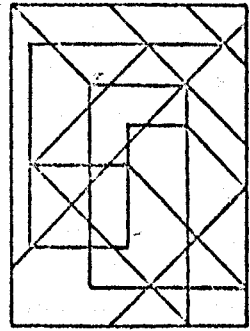
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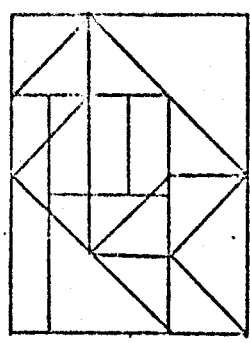
A



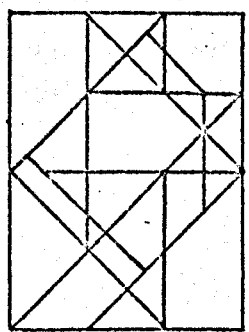
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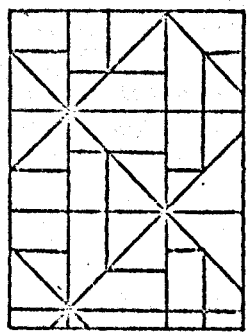
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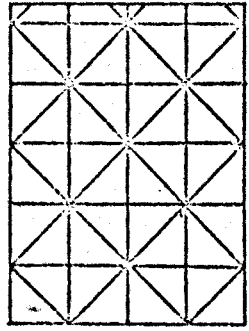
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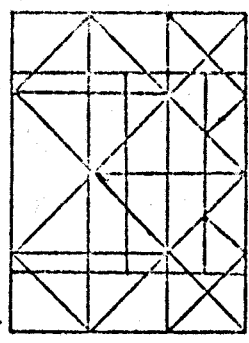
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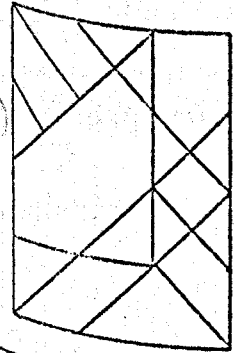
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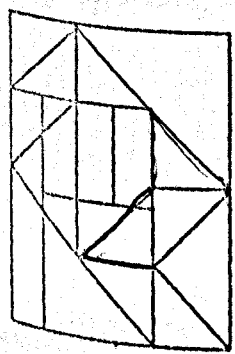
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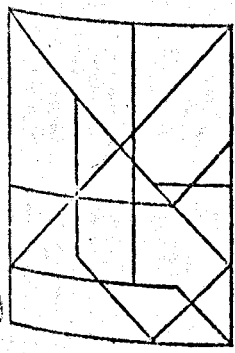
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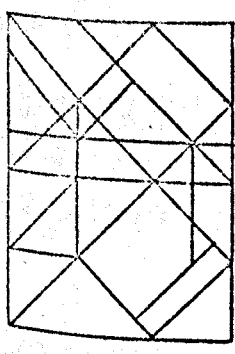
A



B



C



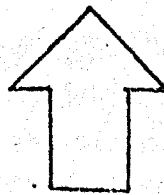
D



9



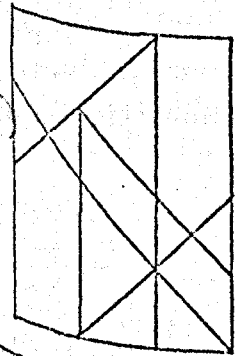
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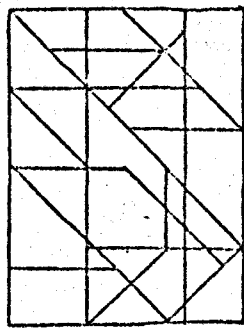
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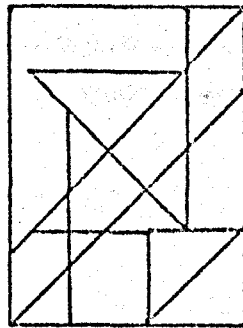
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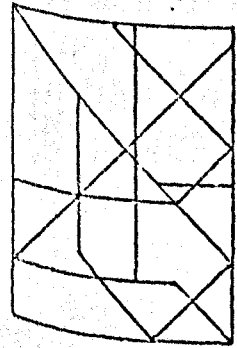
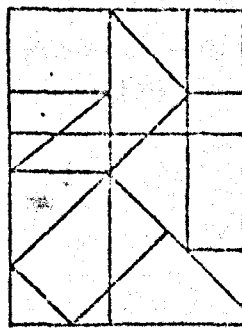
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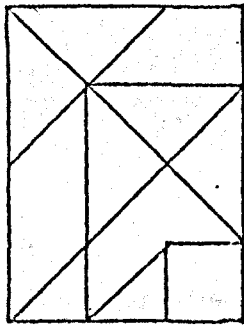
A



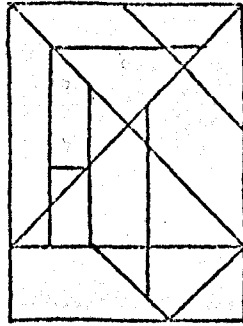
A



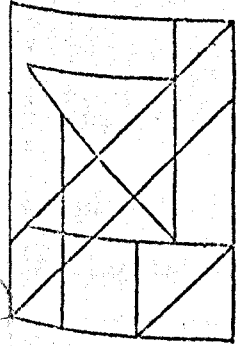
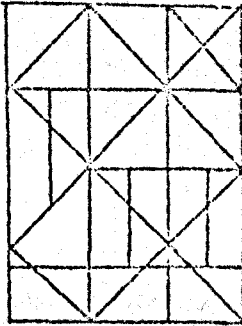
B



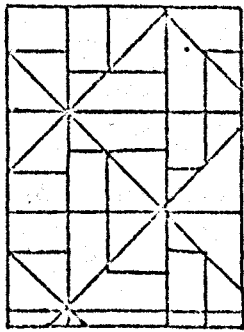
B



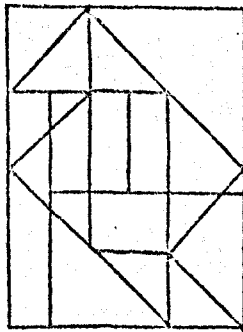
B



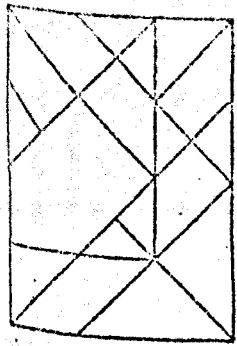
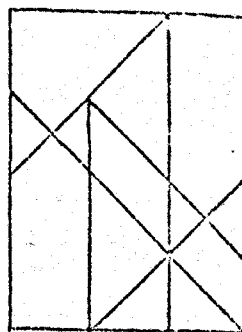
C



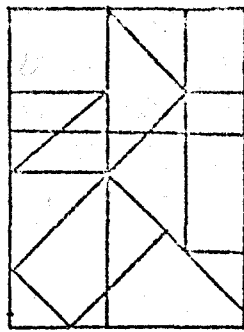
C



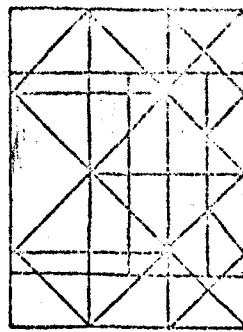
C



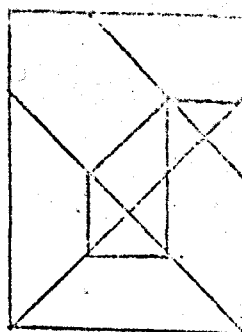
D



D



D



UNIVERSITY OF KEELE
DEPARTMENT OF EDUCATION

Name _____

Date _____

School _____

Male/Female _____

Form _____

HIDDEN FIGURES TEST

ANSWER SHEET

Record your answers as follows:

Put X in the appropriate box if the simple form is hidden in the complex figure.

Put 0 in the appropriate box if the simple form is NOT hidden in the complex figure.

If you are uncertain about whether or not a complex figure contains the simple form, do not mark the appropriate box.

	A	B	C	D		A	B	C	D
1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	7	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	9	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	11	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	12	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

APPENDIX B iv)

Observation test in chemistry booklets

[The following text is extremely faint and illegible due to low contrast and noise. It appears to be a list of items or a table of contents related to chemistry booklets.]

3 A

Name

Teaching Group

School

10

A PERCEPTION EXERCISE IN PRACTICAL CHEMISTRY

Department of Education
The University
KEELE

Summer Term 1979.

B

Name

Teaching Group

School

47

A PERCEPTION EXERCISE IN PRACTICAL CHEMISTRY

62

Department of Education
The University
KEELE

Summer Term 1979

A

INSTRUCTIONS

You will find a series of experiments in this booklet. Record accurately, but briefly, what happens in each reaction.

Write your answer below the instructions in each case.

34 B

INSTRUCTIONS

You will find a series of experiments in this booklet. Answer the question associated with each exercise.

In addition, describe accurately, but briefly, any other changes which may occur.

C.

Name

Teaching Group

School

A PERCEPTION EXERCISE IN PRACTICAL CHEMISTRY

Department of Education
The University
KEELE

Summer Term

C. INSTRUCTIONS

You will find a series of experiments in this booklet. Carry out each one carefully. Record what happens, firstly, by placing crosses in all relevant boxes and then by describing in good English what happens on the preceding page, (opposite). For example, if in a reaction there was a colour change from blue to yellow you would mark the grid;

COLOUR
CHANGES

ONE colour change	
More than ONE colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate redissolves	
A solid dissolves	

A vapour is produced :

HEAT
CHANGES

Heat is given out	
The reaction makes the test-tube colder	

GASEOUS
CHANGES

Effervescence takes place	
A gas condenses to a liquid	
A gas is produced which smells	

Opposite: You would write "The blue solution turned yellow".

A 1 Add 1" of Solution C to 1" of Solution G. Mix well by shaking the tube as you add C.

Answer

A 3 Add 1" of Solution K to 1" of Solution G, shaking the tube as you add Solution K

Answer

A 2 Add 1" of Solution C to 1" of Solution D. Mix well by shaking the tube as you add C.

Answer

A 2 Add slowly, with shaking, 1" of Solution A to 1" of Solution N

Answer

A 5 Add carefully, with shaking, 1" of Solution I to 1" of Solution H.

Answer

A 7 Add carefully, a few drops of Solution F to 1" of Solution B.

Answer

A 5 Add carefully, with shaking, 1" of Solution I to 1" of Solution H

Answer

A 7 Add carefully, a few drops of Solution F to 1" of Solution B

Answer

A 6 Add 2" of Solution A to 1" of Solution M. Mix well as you add A.

Answer

A 8 Add carefully 1" of Solution C to 1" of solution J. Mix well.

Answer

A 2 Add carefully, with shaking, 1" of Solution O to 1" of Solution P.

Answer

A 14 Add 1" of Solution A to 1" of Solution B. Mix well.

Observations.

A 10 Add 1" of Solution C to 1" of Solution E. Shake the tube as you add carefully reagent C.

Answer

A 12 Add 2" of Solid L to 1" of Solution H. Shake the tube and observe this reaction over a period of 5 minutes.

Observation

B1 Add 1" of Solution C to 1" of Solution G. Mix well by shaking the tube as you add C.

Report on any change in temperature :

Other changes

B3 Add 1" of Solution K to 1" of Solution G, shaking the tube as you add Solution K.

Are there any changes involving colour?

Other changes

E2 Add 1" of Solution C to 1" of Solution D. Mix well by shaking the tube as you add C.

Are there any changes involving gases?

Other changes

B4 Add slowly, with shaking, 1" of Solution A to 1" of Solution N.

Is the product of this reaction soluble in water?

Other changes

- B5 Add carefully, with shaking, 1" of Solution I to 1" of Solution H.
Carefully smell the test tube when the solutions have been mixed.

Other changes.

- B7 Add carefully, a few drops of Solution F to 1" of Solution B.
What gaseous change is observed?

Other changes

B6 Add 2" of Solution A to 1" of Solution M. Mix well as you add A.

Comment on the solubility of the reaction product in water :

Other changes

B8 Add carefully 1" of Solution C to 1" of Solution J. Mix well.

Does the smell associated with Solution J disappear in the course of the reaction?

Other changes

B9 Add carefully, with shaking, 1" of Solution O to 1" of Solution P.

What happens to the temperature of P when O is added?

Other changes

B 11 Add 1" of Solution A to 1" of Solution B. Mix well.

Comment on any colour change:

Other changes

B 10 Add 1" of Solution C to 1" of Solution E. Shake the tube as you add carefully reagent C.

Is there a change involving the production of a gas?

Other changes

B 12 Add 2" of Solid L to 1" of Solution H. Shake the tube and observe this reaction over a period of 5 minutes.

What happens to Solid L? --

Other changes

2 Add 1" of Solution C to 1" of Solution G.

Mix well by shaking the tube as you add C.

COLOUR CHANGES

One colour change	
More than one colour change	

SOLID CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT CHANGES

Heat is given out	
The re-action makes the test-tube colder	

GASEOUS CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

2 Add 1" of Solution C to 1" of Solution D.

Mix well by shaking the tube as you add C

COLOUR CHANGES

One colour change	
More than one colour change	

SOLID CHANGES

A precipitate appears	
A precipitate re-dissolves	
A Solid dissolves	

HEAT CHANGES

Heat is given out	
The re-action makes the test-tube colder	

GASEOUS CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

OBSERVATIONS for C2

GENERAL CHANGES

GENERAL CHANGES

GENERAL CHANGES

GENERAL CHANGES

OBSERVATIONS for C3

GENERAL CHANGES

GENERAL CHANGES

GENERAL CHANGES

GENERAL CHANGES

C3 Add 1" of Solution K to 1" of Solution G, shaking the tube as you add Solution K

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

C4 Add slowly, with shaking, 1" of Solution A to 1" of Solution N

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

05 Add carefully, with shaking, 1" of Solution I to 1" of Solution H

COLOUR CHANGES	One colour change	
	More than one colour change	

SOLID CHANGES	A precipitate appears	
	A precipitate re-dissolves	
	A solid dissolves	

HEAT CHANGES	Heat is given out	
	The reaction makes the test tube colder	

GASEOUS CHANGES	Effervescence	
	A gas condenses to a liquid	
	A gas is produced which smells	
	A vapour is observed	

06 Add 2" of Solution A to 1" of Solution M. Mix well as you add A

COLOUR CHANGES	One colour change	
	More than one colour change	

SOLID CHANGES	A precipitate appears	
	A precipitate re-dissolves	
	A solid dissolves	

HEAT CHANGES	Heat is given out	
	The reaction makes the test tube colder	

GASEOUS CHANGES	Effervescence	
	A gas condenses to a liquid	
	A gas is produced which smells	
	A vapour is observed	

Observations for C.6

1	...	...	...
2	...	...	...
3	...	...	...
4	...	...	...
5	...	...	...
6	...	...	...
7	...	...	...
8	...	...	...
9	...	...	...
10	...	...	...

Observations for C.7

1	...	...	...
2	...	...	...
3	...	...	...
4	...	...	...
5	...	...	...
6	...	...	...
7	...	...	...
8	...	...	...
9	...	...	...
10	...	...	...

C7 Add carefully, a few drops of solution F to 1" of Solution B

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

C8 Add carefully 1" of Solution C to 1" of Solution J

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

Observations for C.8

CHANGES

CHANGES

CHANGES

Observations for C.9

Observations for C.9

CHANGES

CHANGES

CHANGES

CHANGES

C9 Add carefully, with shaking, 1" of Solution O to 1" of Solution P

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

C 10 Add 1" of Solution C to 1" of Solution E. Shake the tube as you add carefully reagent C.

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re-dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

Observations for C 10

	A solid dissolves
	A gas condenses to a liquid
	A gas is produced which smells
	A vapour is observed

CHANGES

	Heat is given out
	The reaction makes the test tube colder

	A gas condenses to a liquid
	A gas is produced which smells
	A vapour is observed

CHANGES

	Heat is given out
	The reaction makes the test tube colder

CHANGES

Observations for C 11

	A solid dissolves
	A gas condenses to a liquid
	A gas is produced which smells
	A vapour is observed

CHANGES

	Heat is given out
	The reaction makes the test tube colder

CHANGES

	A gas condenses to a liquid
	A gas is produced which smells
	A vapour is observed

CHANGES

	Heat is given out
	The reaction makes the test tube colder

CHANGES

C11 Add 1" of Solution A to 1" of Solution B. Mix well

Si 0 ref amimvrad0

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re- -dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

C12 Add 2" of Solid L to 1" of Solution H. reaction over a period of 5 minutes.

Shake the tube and observe this

COLOUR
CHANGES

One colour change	
More than one colour change	

SOLID
CHANGES

A precipitate appears	
A precipitate re- -dissolves	
A solid dissolves	

HEAT
CHANGES

Heat is given out	
The reaction makes the test tube colder	

GASEOUS
CHANGES

Effervescence	
A gas condenses to a liquid	
A gas is produced which smells	
A vapour is observed	

Observations for C 12

Time	Location	Observations	Remarks
08:00	Station 1	Clear sky, light breeze	Temperature 22°C
08:30	Station 2	Light rain, overcast	Temperature 20°C
09:00	Station 3	Heavy rain, strong wind	Temperature 18°C
09:30	Station 4	Thunderstorm, hail	Temperature 15°C
10:00	Station 5	Clearing, sun visible	Temperature 18°C
10:30	Station 6	Partly cloudy	Temperature 20°C
11:00	Station 7	Light rain	Temperature 21°C
11:30	Station 8	Overcast	Temperature 22°C
12:00	Station 9	Light rain	Temperature 23°C
12:30	Station 10	Clear sky	Temperature 25°C
13:00	Station 11	Light breeze	Temperature 26°C
13:30	Station 12	Clear sky	Temperature 27°C
14:00	Station 13	Light rain	Temperature 26°C
14:30	Station 14	Overcast	Temperature 25°C
15:00	Station 15	Light rain	Temperature 24°C
15:30	Station 16	Clear sky	Temperature 23°C
16:00	Station 17	Light breeze	Temperature 22°C
16:30	Station 18	Clear sky	Temperature 21°C
17:00	Station 19	Light rain	Temperature 20°C
17:30	Station 20	Overcast	Temperature 19°C
18:00	Station 21	Light rain	Temperature 18°C
18:30	Station 22	Clear sky	Temperature 17°C
19:00	Station 23	Light breeze	Temperature 16°C
19:30	Station 24	Clear sky	Temperature 15°C
20:00	Station 25	Light rain	Temperature 14°C
20:30	Station 26	Overcast	Temperature 13°C
21:00	Station 27	Light rain	Temperature 12°C
21:30	Station 28	Clear sky	Temperature 11°C
22:00	Station 29	Light breeze	Temperature 10°C
22:30	Station 30	Clear sky	Temperature 9°C

APPENDIX B v)

Chemicals used in the observation test in chemistry

Identities of the Solutions used in the Extended Investigation into the effect of Modes of Task Definition on Observational Attainment and in the Post-Test in the Teaching Study.

- A 1.5 M Sodium hydroxide
- B 0.5 M Sulphuric acid + 0.2 M Sodium dichromate
- C 1.25 M Sulphuric acid
- D 0.125 M Sodium carbonate
- E As D plus 10 cm³ Universal Indicator per litre
- F 10 Volume Hydrogen Peroxide
- G (0.125 M Sodium carbonate
(1.5 M Sodium hydroxide
(10 cm³ per litre Universal Indicator
- H 0.5 M Sulphuric acid + Ammonium Metavanadate
(10 g per litre)
- I 0.2 M Sodium Thiosulphate
- J (Copper sulphate 40 g per litre
(880 Ammonia 60 cm³ per litre
- K 1.25 M Sulphuric acid + 0.2 M Magnesium sulphate
- L Treated Magnesium ribbon
(immersed in M Sulphuric acid for 15 seconds
then washed - dried)
- M As K plus 10 cm³ per litre Universal Indicator
- N 0.125 M Zinc sulphate
- O and P Distilled Water

APPENDIX B.vi)

Marking grid for assessment of the observation test
in chemistry.

OBSERVATIONAL TEST

RESULTS

NAME _____

SCHOOL _____

MODE _____

CONC. NO.	SOLIDS			Ther mil	GASEOUS		
	SP	SR	SD		GF	GS	GV
1				<input type="checkbox"/>			
2					<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				
4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				
5						<input type="checkbox"/>	
6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				
7					<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8						<input type="checkbox"/>	
9				<input type="checkbox"/>			
10					<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	<input type="checkbox"/>						
12			<input type="checkbox"/>				
13							

APPENDIX B vii)

Item-analysis details for the multiple-choice test in chemistry

Item No.	Item Label	Item ID	Difficulty Index	Discrimination Index
1			0.15	0.15
2			0.15	0.15
3			0.15	0.15
4	23	23	0.15	0.15
5	31	31	0.15	0.15
6	22	22	0.15	0.15
7	32	32	0.15	0.15
8	33	33	0.15	0.15
9	34	34	0.15	0.15
10	35	35	0.15	0.15
11	36	36	0.15	0.15
12	37	37	0.15	0.15
13	38	38	0.15	0.15
14	39	39	0.15	0.15
15	40	40	0.15	0.15
16	41	41	0.15	0.15
17	42	42	0.15	0.15
18	43	43	0.15	0.15
19	44	44	0.15	0.15
20	45	45	0.15	0.15
21	46	46	0.15	0.15
22	47	47	0.15	0.15
23	48	48	0.15	0.15
24	49	49	0.15	0.15
25	50	50	0.15	0.15
26	51	51	0.15	0.15
27	52	52	0.15	0.15
28	53	53	0.15	0.15
29	54	54	0.15	0.15
30	55	55	0.15	0.15
31	56	56	0.15	0.15
32	57	57	0.15	0.15
33	58	58	0.15	0.15
34	59	59	0.15	0.15
35	60	60	0.15	0.15
36	61	61	0.15	0.15
37	62	62	0.15	0.15
38	63	63	0.15	0.15
39	64	64	0.15	0.15
40	65	65	0.15	0.15
41	66	66	0.15	0.15
42	67	67	0.15	0.15
43	68	68	0.15	0.15
44	69	69	0.15	0.15
45	70	70	0.15	0.15
46	71	71	0.15	0.15
47	72	72	0.15	0.15
48	73	73	0.15	0.15
49	74	74	0.15	0.15
50	75	75	0.15	0.15
51	76	76	0.15	0.15
52	77	77	0.15	0.15
53	78	78	0.15	0.15
54	79	79	0.15	0.15
55	80	80	0.15	0.15
56	81	81	0.15	0.15
57	82	82	0.15	0.15
58	83	83	0.15	0.15
59	84	84	0.15	0.15
60	85	85	0.15	0.15
61	86	86	0.15	0.15
62	87	87	0.15	0.15
63	88	88	0.15	0.15
64	89	89	0.15	0.15
65	90	90	0.15	0.15
66	91	91	0.15	0.15
67	92	92	0.15	0.15
68	93	93	0.15	0.15
69	94	94	0.15	0.15
70	95	95	0.15	0.15
71	96	96	0.15	0.15
72	97	97	0.15	0.15
73	98	98	0.15	0.15
74	99	99	0.15	0.15
75	100	100	0.15	0.15

Notes for the operational evaluation of this test, only those items with discrimination indices above 0.15 and indices of difficulty (probability of correct answer) less than 0.50 were used. The mean discrimination index and difficulty index of the test were 0.15 and 0.15, respectively.

Analysis of Chemistry Theory Test Items

Question	Score of top 27% (H) n = 46	Score of bottom 27% (L) n = 46	Index of	Index of
			Difficulty	Discrimination
			$\frac{H + L}{2n}$	$\frac{H - L}{n}$
1	42	34	0.83	0.17
2	29	20	0.53	0.20
3	35	31	0.72	0.09
4	43	35	0.85	0.17
5	31	14	0.49	0.37
6	28	8	0.39	0.43
7	31	8	0.42	0.50
8	40	21	0.66	0.41
9	7	5	0.13	0.04
10	18	7	0.27	0.24
11	30	14	0.48	0.35
12	28	8	0.39	0.43
13	16	12	0.30	0.09
14	43	20	0.68	0.50
15	44	25	0.75	0.41
16	46	32	0.85	0.30
17	10	14	0.26	-0.09
18	17	5	0.24	0.26
19	19	6	0.27	0.28
20	22	7	0.32	0.33
21	20	7	0.29	0.28
22	40	18	0.63	0.48
23	24	14	0.41	0.22
24	40	24	0.70	0.35
25	10	13	0.25	-0.06
26	22	12	0.37	0.22
27	18	6	0.26	0.26
28	37	28	0.71	0.20
29	45	29	0.80	0.34
30	15	7	0.24	0.17

Note: For the operational evaluation of this test, only those items with discrimination indices above 0.195 and indices of difficulty (facility indices) between 0.25 and 0.80 were used. The mean discrimination index and difficulty index of the 'reduced' test were 0.34 and 0.49 respectively.

APPENDIX B viii)

Instructions to schools for the larger 'one-shot'
case study

1. The test material is divided into two parts, A and B.

2. The test should be carried out, as far as possible, under the following conditions:

3. The test should be carried out in a quiet room, free from distractions.

4. The test should be carried out in a quiet room, free from distractions.

- 1) A test of general intelligence
- 2) A test of verbal ability
- 3) A test of numerical ability

5. The test should be carried out in a quiet room, free from distractions.

6. The test should be carried out in a quiet room, free from distractions.

- 1) A test of general intelligence
- 2) A test of verbal ability
- 3) A test of numerical ability

7. The test should be carried out in a quiet room, free from distractions.

8. The test should be carried out in a quiet room, free from distractions.

9. The test should be carried out in a quiet room, free from distractions.

10. The test should be carried out in a quiet room, free from distractions.

11. The test should be carried out in a quiet room, free from distractions.

12. The test should be carried out in a quiet room, free from distractions.

13. The test should be carried out in a quiet room, free from distractions.

14. The test should be carried out in a quiet room, free from distractions.

15. The test should be carried out in a quiet room, free from distractions.

16. The test should be carried out in a quiet room, free from distractions.

UNIVERSITY OF KEELE

DEPARTMENT OF EDUCATION

An investigation into Observation in Chemistry

The present investigation is centred around one practical session of double period length, i.e. about 70 minutes.

In this, pupils will use one of three modes of guidance (Types A, B and C). This practical test should be carried out, as nearly as possible, under examination conditions.

In addition there are also three ancillary tests, these are -

- 1) The AH4 test of General Intelligence
- 2) A Hidden Figures test
- 3) A colour vision test

I would be extremely grateful if all Members of Staff in charge would carry out the tests in the following order.

1. Session I The Practical (A double period)
2. Session II i) AH4 (As per Manual supplied)
 ii) Hidden Figures Test
 iii) Colour Vision Test

Would Members of Staff also please treat all tests as confidential, since other schools in the area may be participating.

Practical Test

The apparatus consists of 6 marked test-tubes (1" and 2" marks) to be supplied by the University of Keele. An adequate supply of reagents in reagent bottles will also be brought. Would schools please supply racks.

Ancillary Tests

I would suggest that pupils use pencils (and rubbers) for these tests.

Administration

Practical Will supervisors please distribute the A, B and C type pupils in the lab. so that no two pupils using the same guidance mode are together. I will supply a random distribution table to suit your numbers.

Will supervisors please stress that care in mixing and adding reagents is absolutely essential and also remind pupils that Observation includes the use of Sight, Smell and Touch, not merely sight.

The Ancillary Tests

- (i) AH4 - This must be carried out as per the Manual, as it is a Standardised Test.
- (ii) Hidden Figures Test - The instructions are on the question paper. Please note there is to be no guessing here. (Para.4)
Please note also that the stipulated time is stated as 12 minutes; disregard THIS and make the test occupy 17 minutes exactly.
- (iii) Colour Vision Test - Please carry this out in a blacked out room and allow 30 seconds per slide.

I enclose a list of reagents for guidance in Safety Precautions.

APPENDIX C - THE TEACHING STUDY

APPENDIX C i)

The observational pre-test.
Test booklet and chemicals used.

1. To be used,

2. To be used,

3. To be used,

4. To be used, but not to be used if the test is not to be used.

5. To be used.

6. To be used, but not to be used if the test is not to be used.

7. To be used, but not to be used if the test is not to be used.

8. To be used, but not to be used if the test is not to be used.

9. To be used, but not to be used if the test is not to be used.

10. To be used.

11. To be used, but not to be used if the test is not to be used.

12. To be used.

13. To be used.

14. To be used.

15. To be used.

16. To be used.

17. To be used.

18. To be used.

19. To be used.

20. To be used.

21. To be used.

22. To be used.

23. To be used.

24. To be used.

25. To be used.

26. To be used.

27. To be used.

28. To be used.

29. To be used.

30. To be used.

31. To be used.

32. To be used.

33. To be used.

34. To be used.

35. To be used.

36. To be used.

37. To be used.

38. To be used.

39. To be used.

40. To be used.

41. To be used.

42. To be used.

43. To be used.

44. To be used.

45. To be used.

46. To be used.

47. To be used.

48. To be used.

49. To be used.

50. To be used.

TEST OF OBSERVATION

In chemistry, we normally use four of our five senses;

i.e. We look,
We touch,
We hear,
We smell, but unless we are told specifically to do so,
We do not taste.

In this test, we want to see how good your senses are.

After each set of simple instructions, there is a space for you to write down anything that you see, feel, hear or smell connected with the reaction. Be as brief as you can, but write in the best English you can and do not miss any observation out. Don't forget that observation involves TOUCH, SIGHT, SOUND, and SMELL.

Follow the reaction instructions carefully.

DE ASTON SCHOOL, MARKET RASEN

AND

THE EDUCATION DEPARTMENT

UNIVERSITY OF KEELE

PRELIMINARY OBSERVATION TEST

YEAR P.

Name _____

Tutor Set _____

Maths Set _____

Teaching Study

Chemicals used in the Open-Ended Pre-test

White powder in expt. 1	Zinc Oxide
A	M Sulphuric acid
B	0.1 M Lead Nitrate
C	Solid Potassium nitrate
D	Water
E	2 M Sodium hydroxide
F	Solid Ammonium chloride
G	0.125 M Zinc sulphate
J	0.5 M Sodium carbonate
K	Solid Potassium permanganate
L	Magnesium ribbon
M	0.5 M Sodium thiosulphate
N	1.25 M Sulphuric acid + 10 gm. of Ammonium metavanadate per litre

APPENDIX C ii)

Teaching scheme booklets.
Modes A. B. C and continuous
assessment schedule

NAME OF STUDENT

DATE

DE ASTON SCHOOL - MARKET RASEN

in conjunction with the

DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET

CHEMISTRY - YEAR P

MODE A

**Note:- You are required to answer as completely
as you can ALL questions in this Booklet**

Name of Student: _____

Tutor Set: _____

1.0. You are supplied with a Bunsen Burner
Draw it and then neatly label it.

1.1. Close the air hole, turn on the gas tap, having connected the bunsen
and light the bunsen.

Describe how a gauze heats up when placed

(a) At the bottom of the flame

(b) Half-way up the flame

(c) Near the top of the flame

1.2. Now open the air hole and describe the heating effects on a gauze held

(a) At the bottom of the flame

(b) Midway up the flame

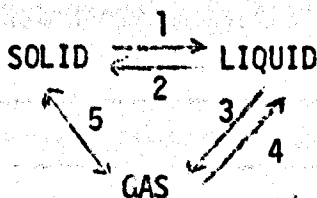
(c) Near the top of the flame

1.3. Carefully put a splint of wood across the bottom of the flame. What happens to it?

1.4. Compare the heating effects of the flame used in 1.1. and that in 1.2.

2.00. STATES OF MATTER

There are three States of Matter, SOLID, LIQUID, and GASEOUS (GAS). The Diagram below shows their inter-relationship.



Find out the names of the processes numbered 1 to 5.

- 1 is _____
- 2 is _____
- 3 is _____
- 4 is _____
- 5 is _____

2.10. You are supplied with a substance which is a solid. Heat it in a small test-tube. Describe what happens to it.

2.11. You are supplied with some liquid. Heat it gently in a test-tube. Describe what happens to it.

2.12. Repeat experiment 2.11. but this time put a clean cold test-tube near the mouth of the test-tube in which the liquid is being heated.

2.13. In a clean dry ignition tube heat a little ammonium chloride. Describe carefully what happens.

Section 3. Purification and its Applications

3.1. DISTILLATION

Aim To obtain pure water from dirty water.

Water normally boils at 100°C and freezes at 0°C .

3.11. Boil dirty water and play the steam onto a cold surface (a cold test-tube).

Observations

3.12. You are given a larger supply of the product from Experiment 3.11. Heat it carefully and describe all that happens. You are provided with a thermometer.

3.13. Repeat experiment 3.12, this time using distilled water. (Pure water).

3.20. Crystallisation

Solids which dissolve in water can be crystallised out again. This enables us to separate such solids from those that do not dissolve.

3.21. Add some isopure X to water and shake. What happens.

3.22. Now warm the mixture from 3.21. What happens?

3.23. Pass the mixture from 3.22. through a folded filter paper in a filter funnel. What happens?

3.24. Warm the liquid product and leave it in a warm draughty area. What happens?

3.30. FRACTIONAL DISTILLATION

When we have a mixture of liquids, they can sometimes be separated by boiling each one off in sequence. If the liquid mixture is too complex however, this procedure is impossible and we divide the liquid up into arbitrary 'cuts' or fractions related to boiling point.

3.31. You will watch an experiment; draw a labelled diagram of the apparatus and describe all that happens.

4.00. Chemical and Physical Changes

So far in our work, apart from burning part of a splint in section 1.3. all we have done is to separate different chemicals from each other; we have not made anything new.

This time, we will use the bunsen, not only to change the state of chemicals (PHYSICAL change), but also to change the nature of the chemical, so that we finish up with a new product (CHEMICAL change).

4.11. Heat a little camphor first (a) in an ignition tube and then (b) on the edge of a gauze, use direct heat (medium flame). Describe what happens in the case of

(a) _____

and (b) _____

4.12. Repeat the experiment with a little powdered zinc. Describe what happens under condition (a).

and under condition (b): _____

4.20. The teacher will repeat this sort of experiment with two quite dangerous chemicals, (SAFETY glasses on!), first with PHOSPHORUS and then with SODIUM. In addition, he will test any gases to see what they do to Litmus paper.

There are substances which turn blue litmus red, these are acids and an opposite kind of substance, an ALKALI, which turns red litmus blue.

4.21. Phosphorus

(a) _____

(b) _____

4.22. Sodium

(a) _____

(b) _____

4.30. You may now try similar experiments with

4.31. Copper

(a) _____

(b) _____

4.32. and Carbon

(a) _____

(b) _____

Tutor Set _____

DE ASTON SCHOOL - MARKET RASEN

in conjunction with the

DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET II

CHEMISTRY - YEAR P5

NODE A

In this booklet there are some more experiments.
You are asked to answer as fully as you can ALL
the questions in this booklet.

Name of Student _____

5.00 The Air

In the previous experiments in Section 4, we found that the presence or absence of air changed the effect of heat on certain chemicals. We will now investigate what it is about the air that leads to these different effects.

Expt. 5.10

Put some water in a small trough to a depth of about 1.5 cm. In the middle of the trough place a small candle. Now light the candle, and when it is burning strongly, place the beaker supplied over the candle so that the rim of the beaker is entirely below the surface of the water.

Describe carefully all that happens and draw a fully labelled diagram of the apparatus.

5.20 THE AIR AND PHOSPHORUS

The teacher will show you an experiment in which phosphorus is allowed to slowly "burn" in air. In this experiment, we use a graduated tube instead of a beaker and smouldering phosphorus instead of a burning candle. A graduated tube enables us to take quite accurate measurements. Describe carefully all that happens and then draw a labelled diagram.

5.20

Diagram

Conclusions

6.00 THE BURNING OF ELEMENTS IN OXYGEN

The teacher will show you some experiments similar to those that were done in Section 4, but this time using only the ACTIVE part of the air, which we call OXYGEN.

6.10 Experiments with NON-METALS

Elements have been divided into two types, Non-Metals and Metals. When we met Non-Metals in Section 4, they gave combustion products that tended to be ACID to litmus.

Only 20 of the 92 naturally occurring elements are Non-Metals. Have the Non-Metals you have met, so far any features in common?

6.11 PHOSPHORUS

Describe all that happens when the non-metallic element Phosphorus is burned in oxygen and the product is treated with Universal indicator.

Now compare Experiment 4.21 with 6.11

6.12 SULPHUR burning in Oxygen

6.13 Carbon burning in Oxygen

6.13

Compare 6.13 with 4.32

6.20 Most of the elements are Metals. They burned to give ALKALINE products in Section 4. Have the metals you have met so far anything in common?

6.21 Magnesium burning in oxygen

Describe all that happens.

6.22 Sodium burning in oxygen

Describe all that happens.

Compare 4.22 with 6.22.

7.10

7.11 Put a glowing splint near the mouth of your test-tube. Again, describe what happens.

Conclusions

7.20 Many of the compounds we have met so far have a second word that ends in -IDE. This tells us that the compound is made up of only TWO elements that have united chemically to give the compound. i.e. Magnesium united with OXYGEN to give Magnesium Oxide. Can you write two more examples?

(1) _____

(2) _____

There are other compounds whose second name ends in -ATE. These compounds contain the two elements which occur in the name, and also oxygen.

For instance, Potassium Nitrate contains Potassium, Nitrogen and Oxygen (ATE) chemically united to form the white crystals.

What elements unite to make

1) Sodium sulphate?

8.00 Other possible ways of producing oxygen

In section 7.00, we made Oxygen by converting Hydrogen Peroxide into Oxygen and Water. Reactions in which one compound gives rise to two, or sometimes even more, chemicals, which can be themselves compounds or elements, are called DECOMPOSITIONS.

We used a catalytic method, where the Manganese Dioxide helped the Hydrogen Peroxide to decompose.

We can also use heat to break down compounds. Therefore, if we take compounds which we know contain OXYGEN (from our naming system) and heat them, if a gas is given off which rekindles a glowing splint, we have another source of oxygen.

8.10 Describe carefully what happens when the following substances are heated. Two of these should be ignored and are put in as red herrings. (Read all names carefully!)

8.11 Potassium chlorate

8.12 Sodium chloride

8.13 Red lead oxide

8.14 Sulphur

8.15 Copper II Carbonate

8.16 Magnesium oxide

8.17 Lead II Nitrate

Conclusions

DE ASTON SCHOOL - MARKET RASEN

in conjunction with the

DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET

CHEMISTRY - YEAR P

MODE B

**Note:- Answer all the questions asked, but also
include all other observations you make.**

Name of Student: _____

Tutor Set: _____

1.0. You are supplied with a bunsen burner.
Locate the jet, and draw it showing its position in the bunsen.

1.1. Close the air hole, turn on the gas tap, having connected the bunsen to the gas supply, and light the bunsen. Place a gauze near the bottom of the flame, then in the middle and then near the top. Which is the hottest position?

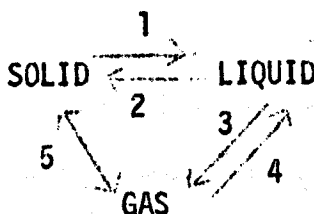
1.2. Now open the air hole and find the hottest spot again.

1.3. Carefully put a splint of wood across the bottom of the flame. What happens to the part of the wood right inside the flame?

1.4. Does the situation with the air hole open produce the hottest flame?

2.00. STATES OF MATTER

There are three States of Matter: Solid, Liquid and Gaseous (Gas).
The diagram below shows their inter-relationship



Find out the names of the processes numbered 1 to 5

- 1 is _____
- 2 is _____
- 3 is _____
- 4 is _____
- 5 is _____

2.10. You are supplied with a substance which is a solid. Heat it in a small test-tube. What happens to the State of the solid when it is heated.

2.11. You are supplied with some liquid. Heat it gently in a test-tube. What happens to the state of the liquid when it is heated?

2.12. Repeat experiment 2.11. but this time put a clean cold test-tube near the mouth of the test-tube in which the liquid is being heated. What happens on the surface of the second tube?

2.13. In a clean dry ignition tube heat a little ammonium chloride. What happens near the top of the ignition tube?

Section 3.0. Purification and its Applications

3.1. Distillation

Aim: To obtain pure water from dirty water. Water normally boils at 100°C and freezes at 0°C .

3.11. Boil dirty water and play the steam on a cold surface (a cold test-tube). What happens to the steam?

3.12. You are given a larger supply of the product from experiment 3.11. Heat it carefully and see how the temperature changes

3.13. This time repeat 3.12. using distilled water (Pure water).

3.20. Crystallisation

Solids which dissolve in water can be crystallised out again. This enables us to separate such solids from those that do not dissolve.

3.21. Add some impure X to water and shake. Does all the solid dissolve?

3.22. Now warm the mixture from 3.21. Does the solid dissolve better?

3.23. Pass the mixture from 3.22 through a folded filter paper in a filter funnel. What emerges from the funnel?

3.24. Warm the liquid product and leave it in a warm draughty area. What remains on the basin?

3.30. Fractional Distillation

When we have a mixture of liquids, they can sometimes be separated by boiling each one off in sequence. If the liquid mixture is too complex however, this procedure is impossible and we divide the liquid up into arbitrary 'cuts' or fractions related to boiling point.

3.31. You will watch an experiment, draw a labelled diagram of the apparatus and explain why the receivers were changed.

4.00. Chemical and Physical Changes

So far in our work, apart from burning part of a splint in section 1.3, all we have done is to separate different chemicals from each other, we have not made anything new.

This time, we will use the bunsen, not only to change the state of chemicals (PHYSICAL change), but also to change the nature of the chemical, so that we finish up with a new product (CHEMICAL change).

4.11. Heat a little camphor

a) in an ignition tube

b) on the edge of a gauze with a direct flame (medium).

What are the states of the products in (a) and in (b)?

Describe all other things you may observe

a) _____

b) _____

4.12. Repeat the experiment with a little powdered zinc. Again describe the state of any products with other information you have detected.

a) _____

b) _____

4.20. The teacher will repeat this sort of experiment with two quite dangerous chemicals (safety glasses on!), first with Phosphorus and then with Sodium. In addition, he will test any gases to see what they do to litmus paper. There are substances which turn blue litmus red, these are ACIDS and an opposite kind of substance, an ALKALI, which turns red litmus blue.

Again describe what happens to the state of any products and to the litmus.

4.21. Phosphorus

a) _____

b) _____

4.22. Sodium

a) _____

b) _____

4.30. You may now try two more substances.

4.31. Copper

a) _____

b) _____

and 4.32. Carbon

a) _____

b) _____

Tutor Set _____

DE ASTON SCHOOL - MARKET RASEN

in conjunction with the

DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET II

CHEMISTRY - YEAR P3

MODE B

Please answer all the questions asked in this booklet, but also include all other observations that you make.

Name of Student: _____

5.00 The AIR

In the previous experiments in Section 4, we found that the presence or absence of air changed the effect of heat on certain chemicals. We will now investigate what it is about the air that leads to these different effects.

Expt. 5.10

Put some water in a small trough to a depth of about 1.5 cm. In the middle of the trough place a small candle. Now light the candle, and when it is burning strongly, place the beaker supplied over the candle so that the rim of the beaker is entirely below the surface of the water.

What happens to the water level inside the beaker?

Draw a fully labelled diagram of the experiment, paying special attention to any change in water levels.

Diagram

5.20 AIR AND PHOSPHORUS

The teacher will show you an experiment in which phosphorus is allowed to slowly "burn" in air. In this experiment, we use a graduated tube instead of a beaker and smouldering phosphorus instead of a burning candle.

Draw a labelled diagram of the experiment and state exactly in terms of length what happens to the air column inside the graduated tube.

Diagram

Conclusions

6.00 THE BURNING OF ELEMENTS IN OXYGEN

The teacher will show you some experiments similar to those that were done in Section 4, but this time using only the ACTIVE part of air, which we call OXYGEN.

6.13

6.20

Most of the elements are Metals. They burned to give ALKALINE products in Section 4. Have the metals you have met so far any features in common?

6.21

Magnesium and Oxygen

What is left when the metal has burned?

6.22

Sodium burning in oxygen

Compare this carefully with the experiment we did in Section 4.22. Concentrate on the two flames.

Expt. 7.10 Add to your Hydrogen Peroxide solution a few specks of the solid black compound, MANGANESE DIOXIDE.
What does the solid appear to do?

7.11 Put a glowing splint near the mouth of the test-tube in which 7.10 is being done. What happens to the glowing splint?

Conclusions

7.20 Many of the compounds we have met so far have a second word that ends in -IDE. This tells us that the compound is made up of only TWO elements that have united chemically together to give the compound, i.e., Magnesium united with Oxygen to give Magnesium Oxide. Can you write two more examples?

(1) _____

(2) _____

There are other compounds whose second name ends in -ATE. These compounds contain the two elements which occur in the name and also oxygen.
For instance, Potassium Nitrate contains Potassium, Nitrogen and Oxygen (ATE) chemically united to form the white crystals.

7.20 What elements unite to make
Cont'd.

1) Sodium Sulphate?

2) Copper Carbonate?

3) Potassium Chlorate?

Conclusions

Diagram

8.00 Other possible ways of producing oxygen

In Section 7.00, we made Oxygen by converting Hydrogen Peroxide into Oxygen and Water. Reactions in which one compound gives rise to two, or sometimes even more, chemicals, which can be themselves Compounds or Elements, are called DECOMPOSITIONS. We used a CATALYTIC method, where the Manganese Dioxide helped the Hydrogen Peroxide to break down. We can also use heat to break down compounds. Therefore, if we take compounds which we know contain OXYGEN (from our naming system) and heat them, if a gas is given off which rekindles a glowing splint we have another source of Oxygen.

8.11 In the following cases, heat the substance named and see if a glowing splint is rekindled. Also record all other observations. Two of the substances are red herrings and should not be on the list. (Check their names very carefully!)

8.11 Potassium chlorate

8.12 Sodium chloride

8.13 Red lead oxide

8.14 Sulphur

8.15 Copper II carbonate

8.16 Magnesium oxide

8.17 Lead II nitrate

Conclusions

DE ASTON SCHOOL - MARKET RASEN

in conjunction with the

DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET

CHEMISTRY - YEAR P

MODE C

In this booklet, there is a series of experiments. To help you in your observations, we have provided check lists. Tick off all that you observe, then write, in correct English, an account of each experiment.

Name of Student: _____

Tutor Set: _____

- 1.0. You are supplied with a Bunsen Burner.
 Select the parts which go to make up the bunsen from the following list and then draw a fully labelled sketch.

- | | | | |
|----------|--------------------------|------------------|--------------------------|
| Jet | <input type="checkbox"/> | Collar | <input type="checkbox"/> |
| Base | <input type="checkbox"/> | Tube (rubber) | <input type="checkbox"/> |
| Chimney | <input type="checkbox"/> | Control Knob | <input type="checkbox"/> |
| Air Hole | <input type="checkbox"/> | Protective cover | <input type="checkbox"/> |

Labelled diagram

- 1.1. Close the air hole, turn on the gas tap, having connected the bunsen to the gas supply, and light the bunsen.
 Place a gauze near the bottom of the flame (A).
 Then place it in the middle of the flame (B).
 Then place it near the top of the flame (C).
 Which of the following combinations gives the correct order of hotness, putting the hottest flame position first?

A B C	
B C A	
C A B	
A C B	
B A C	
C B A	

Observation

1.2. Now open the air hole and investigate positions A, B and C again. Using the previous check list, again describe what you observe about the descending order of hotness.

Observation

1.3. Put a splint of wood near the bottom of the open hole flame. Then select the correct observation(s) from the following list and write it up, describing what happens.

The splint burns

The splint is unaffected

The inner part of the bunsen burns the splint

The outer part of the bunsen burns the splint

1.4. Which setting of the bunsen produces the hotter flames?

Air hole open

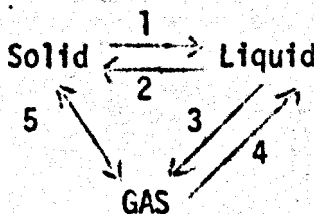
Air hole closed

Air hole partly open

Observations

2.00. States of Matter

There are three States of Matter; Solid, Liquid and Gaseous (Gas). The Diagram below shows their inter-relationship.



Find out the names of the processes numbered 1 to 5

1 is _____

2 is _____

3 is _____

4 is _____

5 is _____

2.10. You are supplied with a substance which is a solid. Heat it in a small test-tube.

Does it?	Solidify		Evaporate	
	Condense		Melt	
	Give a smell		Sublime	
	Dissolve		Boil	
	Change Colour			

Observation

2.11. You are supplied with some liquid. Heat it gently in a test-tube. Using the check list, describe what happens.

Does it?	Evaporate		Solidify	
	Melt		Condense	
	Sublime		Give a smell	
	Boil		Dissolve	

Observations

2.12. Repeat experiment 2.11, but this time put a clean cold test-tube near the mouth of the test-tube in which the liquid is being heated.

Evaporate	
Melt	
Sublime	
Boil	

Solidify	
Condense	
Give a smell	
Dissolve	

Observations

2.13. In a clean dry ignition tube, heat a little ammonium chloride. Describe carefully what happens using the check list as a guide.

Evaporate	
Melt	
Sublime	
Boil	

Solidify	
Condense	
Give a smell	
Dissolve	

Observations

Section 3. Purification and its Applications

Aim To obtain pure water from dirty water
Water normally boils at 100°C and freezes at 0°C.

3.11. Boil dirty water and play the steam on to a cold surface (a cold test-tube). Does the process involve?

Evaporation	
Melting	
Condensation	
Solidification	

Dissolving	
Giving off a smell	
Sublimation	
Boiling	

Description

3.12. You are given a larger supply of the product from experiment 3.11. Heat it carefully. Does the liquid

- Evaporate
- Melt
- Condense
- Solidify
- Sublime
- Dissolve
- Boil

Does its temperature

- Gradually increase all the time
- Gradually increase and then stop
- Not change
- Vary up and down

3.13. Repeat 3.12, this time using distilled water. (Pure water).

3.20. Crystallisation

Solids which dissolve in water can be crystallised out again. This enables us to separate such solids from those that do not dissolve.

3.21. Add some impure X to water and shake.

Does X	Evaporate	
	Condense	
	Melt	
	Solidify	
	Sublime	
	Leave a residue	
	Give a smell	
	Dissolve	
	Refuse to dissolve	

3.22. Now warm the mixture from 3.21. and use the check list in 3.21. to help you decide what happens.

3.23. Pass the mixture from 3.22 through a folded filter paper in a filter funnel. Does the mixture

Remain the same	
Separate	
Have its solid part retained	
Produce a clear colourless liquid	
Produce a clear coloured liquid	
Dissolve	

Observations

3.24. Warm the liquid product and leave it in a warm draughty area.

A shapeless solid is produced	
A regular shaped solid is produced	
Shiny crystals are produced	
The solid is coloured	
The solid is colourless	
A liquid results	
The liquid evaporates	
The liquid boils away	

Use the check list to describe what happens

3.30. Fractional Distillation

When we have a mixture of liquids, they can sometimes be separated by boiling each one off in sequence. If the mixture is too complex however, this procedure is impossible and we divide the liquid up into arbitrary 'cuts' or fractions related to boiling point.

3.31. You will watch an experiment, draw a labelled diagram and describe all that happens, using the following check lists

Apparatus

Flask	Water	
Adaptor	Distillate	
Thermometer	Crude Oil	
Bung	Dirty water	
Condenser		
Receiver		
Bunsen		

(Don't draw supports)

Possible observations

The liquid boils at one temperature	
The " " " several temperatures	
The liquid evaporates	
The gas condenses	
The liquid distils	
All the distillates are alike	
The distillates vary in colour	
The distillates vary in thickness	
The liquids all burn well	
The liquids burn differently from each other	
The solid melts	
The liquids have smells	
The liquid in the flask changes colour	
The vapours are all the same colour	

Diagram

Section 4.00. Chemical and Physical Change

So far in our work, apart from burning part of a splint in section 1.3. all we have done is to separate chemicals from each other; we have not made anything new.

This time, we will use the bunsen, not only to change the state of chemicals (PHYSICAL change), but also to change the nature of the chemical, so that we finish up with a new product (CHEMICAL change).

4.11. Heat a little camphor

a) in an ignition tube

b) on the edge of a gauze with a direct flame (medium).

Describe what happens in each case using the following check list.

The chemical melts	
The chemical burns	
The chemical dissolves	
A gas comes off	
The gas is coloured	
The gas is white	
Heat is generated by the substance	
Heat is needed to make a change	
The chemical evaporates	

Observations

a) _____

b) _____

4.12. Repeat the experiment with a little powdered zinc.

Observations

a) _____

1) _____

4.20. The teacher will repeat this sort of experiment with two quite dangerous chemicals, (Safety glasses on!), first with Phosphorus, and then with Sodium. In addition, he will test any gases to see what they do to litmus paper. There are substances which turn blue litmus red, these are acids and an opposite kind of substance, an ALKALI which turns red litmus blue. Use the check list given in 4.11. and the following checks to describe what happens.

The blue litmus turns red	
The red litmus turns blue	
There is no change in red litmus	
There is no change in blue litmus	

4.21. Phosphorus

a) _____

b) _____

4.22. Sodium

a) _____

b) _____

4.30. You may now try similar experiments with

4.31. Copper

a) _____

b) _____

and 4.32. Carbon

a) _____

b) _____

Tutor Set: _____

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DEPARTMENT OF EDUCATION - UNIVERSITY OF KEELE

REPORT BOOKLET II

CHEMISTRY - YEAR P4

MODE C

In this booklet, there is a second series of experiments. To help you in your observations, we have provided check lists. Tick off all that you observe, then write, in correct English, an account of each experiment.

Name of Student: _____

5.00 The Air

In the previous experiments in Section 4, we found that the presence or absence of air changed the effect of heat on certain chemicals. We will now investigate what it is about the air that leads to these different effects.

Expt. 5.10

Put some water in a small trough to a depth of about 1.5 cm. In the middle of the trough, place a small candle. Now light the candle, and when it is burning strongly, place the beaker over the candle so that the rim of the beaker is entirely below the surface of the water.

Describe carefully what happens using the check list. Then draw a labelled diagram of the apparatus.

The candle continues to burn normally	
The candle goes out	
The water level inside the beaker rises	
The water level inside the beaker falls	
All the air is used up	
Some of the air is used up	
None of the air is used	
The inside of the beaker turns moist	
The inside surface of the beaker is unaffected	

Labelled diagram

5.20 AIR AND PHOSPHORUS

The teacher will show you an experiment in which phosphorus is allowed to slowly "burn" in air. In this experiment, we use a graduated tube instead of a beaker and smouldering phosphorus instead of a burning candle. Describe the experiment and include a labelled diagram.

Check List

The initial length of the air column = cm.
The final length of the air column
after cooling = cm.

<input type="checkbox"/> The water level in the tube rises	
<input type="checkbox"/> The water level in the tube falls	
<input type="checkbox"/> All of the air is used up	
<input type="checkbox"/> Some of the air is used up	
<input type="checkbox"/> None of the air is used up	

Diagram

Conclusions

6.00 COMBUSTIONS IN OXYGEN

The teacher will show you some experiments similar to those that were done in Section 4, but this time using only the ACTIVE part of air, which we call OXYGEN.

6.10 Experiments with NON-METALS

Elements have been divided into TWO types, Non - Metals and Metals. When we met NON-METALS in Section 4, they gave combustion products that tended to be ACID to litmus. Only 20 of the 92 naturally occurring elements are NON-METALS. Have the non-metals you have met so far any features in common?

Similar state	
Similar appearance	
Similar hardness	
Similar colours	
Brittle	
Tough	

6.11 PHOSPHORUS burning in oxygen

Describe what happens using the following check list for this experiment and all those through to 6.23.

The element (metal/non-metal) melts	
The element burns	
The element dissolves	
A gas comes off	
A liquid is produced	
A solid is the product	
The gas is coloured	
The gas is white	
Heat is generated	
Heat is needed	
The element evaporates	
Blue litmus turns red	
Red litmus turns blue	
The litmus does not change	
The element burns with a coloured flame	

Compare 6.11 with 4.21

The combustion in 6.11 is fiercer than in 4.21	
The effect on litmus is the same	
The effect on litmus is different	
The combustion in 6.11 is slower than in 4.21	

6.12 Use the check list associated with 6.11 to describe what happens when sulphur burns in oxygen.

6.13 Use the check lists associated with 6.11 to describe what happens when carbon burns in oxygen.

Also compare reaction 6.13 with 4.32

6.20 Most of the elements are metals. They burned to give ALKALINE products in Section 4. Have the metals you have met so far any features in common?

6.21 Use 6.11's check list to help you in your description

6.21
Cont'd.

6.22 Sodium burning in oxygen

Describe what happens

Compare Experiment 6.22 with Experiment 4.22

6.23 Iron burning in oxygen

Conclusions

Cont'd...

7.00 OXYGEN

Since oxygen is obviously such an extremely useful element, we need to know a great deal about it. It supports our life and we have all probably heard of oxygen being administered from cylinders to patients who find breathing difficult. Can you think of other instances where people use 'additional' oxygen for breathing?

A compound called HYDROGEN PEROXIDE is used in rockets to supply oxygen in outer space; we shall use a diluted form of this liquid in our laboratory experiments.

Expt. 7.10

Add to your Hydrogen Peroxide solution a few specks of the solid black compound MANGANESE DIOXIDE
What happens?

The liquid warms up	
The liquid cools at first	
A gas is evolved	
The gas is coloured	
The gas smells	
The solid dissolves	
The solid is unaffected	
The liquid evaporates quickly	

Expt. 7.11 Put a glowing splint near the mouth of the test-tube holding reaction 7.10. What happens?

The splint goes out	
The splint is unaffected	
The splint brightens	
The splint bursts into flame	
The splint bursts into flame noisily	

Conclusions

7.20 Many of the compounds that we have met so far have a second word that ends in -IDE. This tells us that the compound is made up of only TWO elements that have united chemically to give the compound, T.e. Magnesium united chemically with Oxygen to give Magnesium Oxide. Can you write two more examples?

(1) _____

(2) _____

There are also compounds whose second name ends in -ATE. These compounds contain the two elements which occur in the name and also oxygen.

For instance, Potassium Nitrate contains Potassium, Nitrogen and Oxygen (ATE) chemically united to give the white crystals. What elements unite to make:

1) Sodium Sulphate?

to two, or sometimes even more, chemicals, which can be themselves compounds or elements, are called DECOMPOSITIONS. We used a catalytic method, where the Manganese Dioxide helped the Hydrogen Peroxide to break down.

We can also use heat to break down compounds. Therefore, if we take compounds which we know contain OXYGEN (from our naming system) and heat them, if a gas is given off which rekindles a glowing splint, we have another source of oxygen.

- 8.10 Describe what happens when the following substances are heated. (Two of the chemicals should be ignored and are put in as red herrings. Read all names carefully). Use the check list provided.

Check list for experiments 8.11 to 8.17 inclusive:

A glowing splint is rekindled	
A glowing splint is extinguished	
There is no change in the glowing splint	
The solid melts	
There is an effervescence	
The gas smells	
The gas is coloured	
The solid changes colour once	
The solid changes colour more than once	
The solid is unaffected	
The solid sublimates	
The liquid boils	

- 8.11 Potassium chlorate

- 8.12 Sodium chloride

- 8.13 Red lead oxide

8.14 Sulphur

8.15 Copper II Carbonate

8.16 Magnesium oxide

8.17 Lead II nitrate

Conclusions

MARKING SCHEMES USED IN THE CONTINUOUS ASSESSMENT OF
THE PRACTICAL WORK IN THE MEDIUM TERM TEACHING PROJECT

Section 1.

Sub. Division	Description	Observation Marks
1.0	Not observational	Nil
1.1	Three observations of heating effects	3
1.2	Three observations of heating effects	3
1.3	Heating effect with two observations	2
1.4	A deduction required	Nil
	Sub. Total	8

Section 2.

Sub. Division	Description	Observation Marks
2.00	Cognitive Work	Nil
2.10	Melt, Boil, Smell, Evaporate Solid disappears, Solid re-appears	6
2.11	Liquid boils, evaporates, condenses	3
2.12	Boiling and evaporation More effective condensation	1 2
2.13	Evaporation (solid disappears) Solidification Smoke Smell	4
	Sub. Total	16

Section 3.

Sub. Section	Description	Observation Marks
3.11	Recapitulation of Evaporation and Condensation	1
	Formation of Residue	1
3.12	Evaporation	1
	Boil and Condense	1
	Increase in temperature	1
	Stabilised Higher Temperature	1
3.13	Similar to 3.12 ∴ only half marks	2
3.21	Some solid dissolves	1
	Some black does not	1
3.22	Increased solubility of the 'soluble' one	1
3.23	Clear colourless filtrate	1
	Retained solid	1
3.24	Evaporation	1
	White residue	1
	Crystalline solid	1
3.31	No independent observation. Didactic technique	Nil
Sub. Total		16

Section 4

Sub. Section	Obs. Item. (Description)	Obs. Marks
4.11 (a)	Recapitulation of 2.10 ;half value	3
4.11 (b)	Combustion Heat generated Smoke Black residue	4
4.12 (a)	Melting/Solidification	1
(b)	Heat generated Yellow solid White when cold	3
4.21 (a)	Melts and solidifies Slight fuming	2 1
(b)	Heat White fumes Flames Blue litmus red	4
4.22 (a)	Melt and solidify	2
(b)	Melt Burn Heat Solid residue Litmus red blue	5
4.31 (a)	No change	1
(b)	Black residue	1
4.32 (a)	No change	1
(b)	Red hot Grey ash	2
4.33 (a)	No change	1 extra item
(b)	Melt Burn Intense heat White product Litmus red blue	5

Sub. Total 36

Sections 5 and 6.

Sub. Section	Description	Obs. Marks
5.10	Candle goes out Water level rises Condensation inside the beaker Air disappears	4
5.20	White fumes	1
6.11	Bright yellow flame Indicator red <u>Fierce</u> combustion White gas and heat	1 1 1 1
6.12	Blue flame Fiercer combustion than in air White gas, Indicator red	1 1 1
6.13	Red heat - more so than in air U.I. yellow	2 1
6.21	Very bright flame Fierce combustion White residue, purple U.I.	1 1 1
6.22	Bright yellow flame Fierce combustion White residue. U.I. Alkaline	1 1 1
6.23	White hot Solid residue U.I. slightly alkaline	1 1 1
	Sub. Total	24

Note: 5 - 6 combined because of the small size of section 5.

Section 7 and 8. Combined because of the shortness of section 7.

Sub. Section	Description	Obs. Marks
7.10	Solid unaffected	1
	Gas evolved	1
	Warmer	1
7.11	Rekindling or brightening	1
8.11	Melting, Effervescence, Colour change	3
	Sublimation, Rekindling	2
	White residue	1
8.12	No observations	
8.13	Brown when hot	1
	Yellow when cold	1
	Melting	1
	Rekindling	1
8.14	No observations	
8.15	Solid goes black	1
	Splint extinguished	1
8.16	No change in solid	1
	Splint extinguished	1
8.17	Brown fumes. Rekindling	2
	Smell	1
	Crackling	1
	Melting	1
	Solid yellow	1
	Boiling occurs	1
	Red(hot)	1
	Yellow(cold)	1
	Total	27



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The following has been redacted from this digital copy of the original thesis at the request of the awarding university:

Appendix C, iii

APPENDIX C iv)

Raw scores of all sub-groups on
observational course-work

Raw Scores of all groups obtained on the different sections of the observational teaching programme.

Raw Scores on Teaching Programme Sections

<u>Open Ended Groups</u>		1	2	3	4	5/6	7/8	TOTAL
Year P	\bar{x}	6.20	8.60	9.30	22.60	18.00	10.20	75.40
n = 20	S.D.	0.93	1.53	1.87	3.65	2.43	2.46	7.19
Year R	\bar{x}	6.86	10.50	9.95	19.90	18.04	12.86	77.95
n = 22	S.D.	0.75	2.03	1.64	2.76	2.78	1.60	6.26
Year S	\bar{x}	6.22	8.61	8.50	19.16	16.94	10.11	69.56
n = 18	S.D.	1.03	1.74	1.42	2.08	2.37	1.88	5.99

Partial Direction Groups

Year P	\bar{x}	7.00	9.35	10.69	21.92	17.00	12.92	78.88
	S.D.	1.21	1.43	1.43	2.78	1.71	2.88	5.16
Year R	\bar{x}	6.61	9.54	10.12	18.61	18.26	10.19	73.35
	S.D.	2.16	2.00	1.80	2.89	2.55	4.15	8.27
Year S	\bar{x}	3.75	6.75	8.40	16.25	15.10	9.11	59.40
	S.D.	0.99	1.89	1.39	2.49	2.14	1.37	5.45

Check List Groups

Year P	\bar{x}	7.62	12.57	14.00	24.19	19.00	13.53	90.92
	S.D.	0.56	1.59	0.96	2.40	1.14	2.69	5.02
Year R	\bar{x}	7.20	9.32	11.44	20.72	18.72	15.48	83.28
	S.D.	1.29	2.14	1.29	1.82	2.31	2.85	4.01
Year S	\bar{x}	5.33	7.22	9.27	17.28	16.72	12.18	67.94
	S.D.	1.89	1.78	1.59	2.64	2.70	3.47	7.66

APPENDIX D

Material Associated with the Problem-Solving Study

APPENDIX D i)

Problems used in the Study

PRACTICE

Problem 1

These observations were made in experiments conducted with Solid A, a simple salt.

1. This white crystalline solid appeared to dissolve in distilled water to give a colourless solution.
2. When A was heated strongly in a small tube it crackled, melted, turned yellow and evolved brown fumes. When it was hot it went red and returned to a yellow colour on cooling.
3. Dilute hydrochloric acid appeared to have no effect on Solid A.
4. A few drops of concentrated sulphuric acid were added to Solid A and it was warmed. The liquid turned murky white and a yellow oily condensate appeared on the cooler parts of the tube. Brown fumes also appeared.
5. a) A solution of the solid in distilled water was treated with a solution of potassium iodide. A yellow ppt. soluble in hot water resulted.
b) Sodium hydroxide solution was added to an aqueous solution of A. This gave a white ppt. soluble in excess alkali.

What is A?

Problem 2

This data relates to Solid B

1. Appearance Pale green crystals.
2. Solubility in water. Soluble giving yellow-green solution.
3. Action of heat on Solid B. This solid turns white then brown-black. It gives off pungent white fumes which turn moist blue litmus red and dichromate paper green. On protracted heating, the type of smell changes and red litmus reverts to blue.
4. Action of dilute hydrochloric acid on Solid B A colourless solution is obtained.
5. Concentrated sulphuric acid to Solid B. There is no action apart from a slight dissolution.

The following reagents were added to a solution of B in water.

6. Dilute sodium hydroxide solution. Dirty green ppt. and a pungent smell on warming. Red litmus (moist) goes blue.
7. Potassium hexacyanoferrate (II) solution (Potassium ferrocyanide) Medium blue ppt.
8. Potassium iodide solution No action.
9. Barium chloride solution White ppt. insoluble in hot, concentrated hydrochloric acid.
10. Silver nitrate solution to a solution of B in dilute nitric acid. No action.

Problem 4

The following tests were carried out on Solid D, a mixture of two salts.

1. Solid D was treated with dilute nitric acid. Solid D dissolved with effervescence to give a colourless solution.
The gas turned limewater milky but did not affect potassium dichromate paper.
2. The Solution from (i) was divided into three portions and the following tests carried out on it:
 - a) Dilute sulphuric acid was added to the first portion. A white ppt. was obtained, insoluble in hot ammonium sulphate solution.
 - b) Barium chloride solution was added to the second portion. A white ppt. soluble in hot concentrated hydrochloric acid was obtained.
 - c) Sodium hydroxide solution was added to a third portion. A white ppt. soluble in excess sodium hydroxide was obtained.
3. Finally a sample of the mixture was heated strongly. The solid melted, gave off brown fumes and when it had cooled turned to a yellow solid.

Problem 5

This data relates to Solid E

1. Appearance Off white powder, slightly lumpy.
2. Solubility in water E was partially soluble, the temperature dropped and the supernatant liquid was colourless
3. Action of heat on E E melts, boils, and then solidifies. It gives off a white vapour which partially condenses. The vapour turns moist blue litmus red. The solid residue is white.
4. Action of dilute hydrochloric acid No action with cold acid, but when it is warmed a pungent smell is evolved. This gas turns moist blue litmus paper red and potassium dichromate paper green. The solution remaining is colourless.
5. Action of concentrated sulphuric acid Immediate effervescence and then pungent white fumes turn moist blue litmus red, and potassium dichromate paper green. They also turn a silver nitrate acidified with dilute nitric acid, drop milky.

The following reagents were added to a solution of E in dilute hydrochloric acid:

6. Sodium hydroxide solution White ppt. insoluble in excess sodium hydroxide solution
7. Ammonium hydroxide solution No action
8. Potassium hexacyanoferrate (II) solution (potassium ferrocyanide) No action
9. Barium chloride solution White ppt. almost completely soluble in hot concentrated hydrochloric acid.
10. Silver nitrate solution to a solution of E in dilute nitric acid Chunky white ppt. which dissolves fairly obviously when shaken with dilute ammonium hydroxide solution. The residual precipitate left begins to go grey.
11. Sulphuric acid (dilute) was added to a concentrated solution of E White ppt. soluble in hot ammonium sulphate

APPENDIX D -ii)

Copy of the analysis scheme and instruction sheet sent prior to the problem-solving sessions.

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The analysis of Simple Salts

The following radicals are to be considered: Zinc, Iron (II), Iron (III), Calcium, Lead (II), Copper (II), Ammonium, Sulphate(VI), Nitrate (V), Chloride, Sulphate (IV), Sulphide and Carbonate.

General Points to Consider

Salts of Iron and Copper tend to be coloured and produce coloured solutions.

Carbonates of your metals are usually INSOLUBLE in water.

Nitrates and Ammonium salts are soluble.

Lead salts have a tendency to be INSOLUBLE except for the NITRATE.

<u>TEST</u>	<u>OBSERVATION</u>	<u>INFERENCE</u>
1. Heat the salt in a small tube.	The solid sublimes, litmus goes blue. On <u>rare</u> occasions it can then go red again.	Ammonium
	The solid turns black.	Copper(II) or Iron
	The solid goes red brown.	Iron (or Copper)
	Solid goes yellow when hot white when cold.	Zinc
	Solid goes red when hot, yellow when cold.	Lead
	Brown fumes evolved.	Nitrogen dioxide evolved therefore Nitrate(V) present
	Gas evolved which turns limewater milky.	Carbon Dioxide evolved therefore Carbonate present
2. Add dilute hydrochloric acid to the solid, warming if necessary.	Gas evolved which turns pot. dichromate paper green.	Sulphur dioxide evolved Sulphate (VI) present.
	Gas evolved, usually on warming, which turns dichromate paper green.	Sulphur dioxide evolved therefore Sulphate (IV) present, (Sulphite)
	Gas evolved immediately which turns limewater milky.	Carbon dioxide evolved therefore Carbonate.
	Gas evolved with bad egg smell which turns lead acetate paper black.	Hydrogen Sulphide evolved Sulphide present

NOTE: If you suspect a Sulphate (IV) to be present in test 2, before you test for carbonate add a little solid potassium dichromate to the solid, then add the dilute acid. The dichromate removes sulphur dioxide which can interfere with limewater. Therefore any CO₂ present will now show up.

- | | | | |
|----|---|--|--|
| 3. | Add concentrated sulphuric acid, a few drops only, to the solid. Warm gently. | Effervescence and a choking gas which fumes in air is evolved, which turns a silver nitrate (V) drop milky.

Oily condensate observed when the mixture is warmed and brown fumes are detected. | Hydrogen chloride evolved.
Chloride present.

Nitrate |
| 4. | A solution of sodium hydroxide is added to a solution of the salt dropwise to excess, with constant shaking. | White ppt. soluble in excess alkali
White ppt. insoluble in excess alkali
Green, jelly like ppt.
Red, Brown, jelly like ppt.
Blue, jelly like ppt.
Gas evolved with turns red litmus blue and smells of ammonia on warming. | Zinc or Lead (II)

Calcium

Iron (II)
Iron (III)

Copper (II)
Ammonium present |
| 5. | Add a solution of Barium chloride to a solution of the salt | White ppt. insoluble in hot concentrated hydrochloric acid

White ppt. soluble in hot concentrated hydrochloric acid | Sulphate (VI)

Sulphate (IV)
(Sulphite) |
| 6. | Add a piece of copper to a small quantity of solid followed by about 1cm ³ of concentrated sulphuric acid and warm CAREFULLY | Brown fumes and oily drops condensing in the tube. Greeny or blue solution | Nitrate (V) |

OTHER TESTS

- | | | | |
|----|---|---|--|
| a) | Add potassium iodide solution to a solution of the salt. | Yellow ppt. soluble in hot water

White ppt. in a brown solution | Lead (II)

Copper (II) |
| b) | Potassium Hexacyanoferrate(II) (II) solution (ferrocyanide) to a solution of the salt | Light blue ppt.
Deep blue ppt.
Brown ppt.
White ppt. soluble in sodium hydroxide solution. (The ppt. can be discoloured) | Iron (II)
Iron (III)
Copper (II)
Zinc
Lead |
| c) | Add dilute sulphuric acid to a concentrated solution of the salt. | White ppt. soluble in hot ammonium sulphate solution | Calcium |

- d) Add Ammonium hydroxide to a solution of the salt
Pale blue ppt. dissolving in excess ammonia - Deep blue solution
Copper (II)
- e) Dissolve the salt in dilute nitric acid, then add silver nitrate solution.
white ppt. turning grey, soluble in ammonium hydroxide solution
Chloride

UNIVERSITY OF KEELE

THE INTERPRETATION OF OBSERVATIONAL DATA

INSTRUCTIONS

1. You are provided with some notes on salt analysis. Familiarise yourself with these.
2. Later you will be given a booklet containing five problems relating to salt analysis. These represent real life situations and so the data given to you may vary from 'inadequate' through 'correct' to excessive. The first problem is a "specimen" for you to obtain familiarisation with the mechanics of the procedure. It will not be assessed.

3. Mechanics of the Solution

Read through the problem to gather in the scope of the tests with both sides of the salt analysis sheet available to you. When you have read through these switch on the tape recorder and solve, or attempt to solve the problem by thinking aloud, revealing the results of the tests one by one to simulate a 'laboratory' situation. Do not switch the recorder off until you have reached a conclusion or reached a point when you feel the problem is insoluble. In either case, state your conclusion or the fact that no conclusion appears to be possible.

Will you prefix each answer by your code letter and the problem number please?

4. Each problem refers to a combination of two salts.
5. Do not make notes - we want to explore pure thinking with no assistance from written prompts.

APPENDIX D iii)

Transcripts of the taped protocols.

It is to be noted that the figures shown in the course of the transcripts indicate periods of silence. (seconds)

Caistor Tapes 'K'

(2) Well, pale green green crystals, that would indicate to me that is, it, could be -um-erm-um because and iron is green when its in water, no - but this is a solid isn't it. O dear erm, it it could be iron.

Solid gives a yellow-green solution - erm - well it would - the metal - the - part of this salt must be - erm - part of a transition - metal because it - they - give colour - colour compounds, so that can rule out calcium and erm lead and - yellowy green? erm - it could be iron and copper - or copper, and its soluble so it could have part of a nitrate or ammonia compound and erm - it couldn't be carbonate because they're insoluble in water and it, it could be lead, but I don't think so - er mainly, it's iron or maybe nitrate and ammonia compound.

Ah! if the solid turns white, then brown-black er-um-it-brown black solid it could be copper II or iron here and -erm white then brown black, it could be copper II or iron. The pungent white fumes, that could be? chlorine? um - chlorine gives off a smell! but it then - it could also be ammonium I think. I think its probably ammonium - erm - and the red litmus um - does go blue. It does go blue if it is ammonium, so I thinks its probably ammonium and either copper II or iron's. I think probably is iron - iron ammonium - iron II ammonium?

Erm - turns dichromate paper green - it could be, er there's it could be sulphur dioxide instead of ammonium, so which would indicate a sulphate (VI) iron present, so it could be er, iron II, iron, copper II or - with ammonium or sulphate (VI). Solution was obtained - erm - this compound, would probably

dissolve in hydrochloric acid - there are no gases given off
erm - I should think this compound must be just soluble.

(JEW Does it cause you to eliminate anything? The fact
that you said a gas doesn't come off)

Colourless solution! I said it was iron or copper or
ammonium and sulphur dioxide - erm. I should think it possibly
isn't sulphur dioxide, I don't know!

(JEW I'm not saying you can eliminate, I'm just throwing it up)
If no gases do come off its probably ammonium. I'm not sure.
I should think - no - I should think there probably is a
sulphate if - perhaps it - if it was ammonium perhaps the gas
would be given off then - so I think there is probably, is a
sulphate (VI).

Er - the green ppt. - um - that could be iron II, on warming,
so it could - or it could be ammonium because that would give
off a smell on warming, and er - it would turn red litmus
paper blue, so it probably is iron II ammonium.

Potassium - deep blue? ah now! it could be iron III now, if
it was a light blue ppt - medium blue? It could be iron II
or iron III. No action! well there's no action - it won't
be lead II or copper II and um, if it is iron - iron iodide?
would be formed - but - no! I think its probably an iron II
or III - er it just says it won't be lead II or copper II,
I think.

Insoluble when hot, Ah! this definitely says to me, proves to
me its a sulphate (VI), from the test result. So I think
its definitely a sulphate. No action? Well this tells me
that it won't be a chloride - as it has no effect, and if it
is - if it's a sulphate you wouldn't you'd probably get silver
sulphate? Maybe - I don't know. Well, it shows that its not
a chloride, it'll be a sulphate. So I think, on the whole its

probably iron sulphate - I don't - think - it could be iron III sulphate. I think its iron sulphate, iron II sulphate.

Follow up after this answer by JEW

(JEW Why have you gone off the ammonium?)

Er - could be ammonium now (giggles) 'cause gas is given off when it's heated - with the smell! and the litmus paper too gives, er, gives it as if it were ammonium. But, with the sulphur dioxide test, it does turn potassium dichromate paper green.

(JEW So you'd conclude that there was ammonium sulphate and iron?)
Yes, I ruled out copper because it, with sodium hydroxide it was a dirty green ppt. not a blue jelly like ppt. as that's why I ruled out copper - it could - yes - probably is ammonium and um sulphate, so I can't really rule out ammonium, cause the test for ammonium is positive for that as well. It's probably a double salt, then, I think - yes, because its true for both of them - I think its a double salt with Iron II, Ammonium and Sulphate VI.

(3) A turquoise powder - that tells me - that makes me think straight of copper - um probably a transition metal too, I think it may be copper - it would be one of the other two transition metals but you can rule out calcium and lead. so zinc? think zinc is gives white? ah, it would, Oh, I don't think it is zinc it could be copper or iron II or iron III I think.

(JEW would you like to make anything of the powder or not?)
from your experience

A powder? I think - it's more likely it is a copper salt it could be zinc II. I think with iron it would be something different, I don't know at this stage.

(JEW You don't want to commit yourself - good!)

Blue solution - ah - I think - shaken with water erm - residue - a blue solution makes me think of copper sulphate but I think I'll stick with copper - leaves a solid residue - no - it could be er a carbonate, it could be carbonate at the bottom, it is insoluble? erm - salts of iron - copper give coloured solutions - so I think it probably is copper, a form of copper and erm I don't think its lead.

(JEW Instinct would say sulphate would it?)

Yes, that's what I think, sulphate, coppersulphate.

(and possibly the solid residue carbonate)

Yes.

Ah - solid turned brown black, that makes me think again its copper, or copper II. It could be iron but I think its probably copper, turned litmus paper red, so there'll be an acidic gas coming off, but there are no fumes, I don't, I think, if there were fumes I think carbonate would give off fumes - could be copper sulphate I think and no fumes given off? The brown black probably is copper oxide or iron oxide - and no fumes given off erm - well it can't if there are no fumes given off, it can't be a carbonate because carbon dioxide will be given off then, and will turn limewater, it can't be nitrogen dioxide because thats usually evolved - and sulphur dioxide is evolved too, so that doesn't show the presence of sulphate. I'll I feel sure its copper but I'm not sure about the other two.

(JEW Your're not too happy about the others?)

(JEW Does this help?)

Milky smell.

Erm - so - potassium dichromate wasn't put in first and if it was a sulphate present, but - we wanted a sulphate to be present, first - then you'd have to do that first, the limewater went milky, that would tell me erm to go for a carbonate - and erm effervescence at which a gas is being given off that would

make me go to carbon carbonate, probably carbon dioxide being given off if dichromate paper, it hasn't - if dichromate paper doesn't has no effect by the gas, so it would be a sulphite and SO_3 , SO_2 isn't given off - and if it there isn't any smell it can't be ammonium or sulphate because they smell, when they come out - there's usually a salt associated with sulphur dioxide. So I think there'd be copper carbonate - at the moment. Copper carbonate.

(JEW Still leaves you with this problem of the blue solution if I may push you back to that)

An immediate (7) No smells (3) now - (3) there aren't any smells - so - it wouldn't be a chloride - hydrogen chloride coming off and there's no erm no smell was detected so it couldn't be a sulphate - sulphur dioxide coming off - it was observed in the cold. I should think CO_2 was being given off um - 'cause CO_2 does not usually need to very hot - to be given off - no smell was detected. Sulphur dioxide wasn't coming off nor hydrogen chloride no changes occurred later on that would probably mean all the CO_2 , if it is CO_2 all the CO_2 would have gone out, left the solution and left, just the copper probably be copper sulphate then having reacted with sulphuric acid, maybe some water, but then on No. 2 test there is a blue solution, so sulphate could be present, so I think its probably copper, a sulphate and a carbonate, a double salt.

(4) Now - with effervescence a gas is given off but it could be - well it won't - if it was brown fumes coming off it would be from the nitric acid - and NO_2 gas coming off but its just a gas without any colour or smell. So - it gives a colourless solution.

(JEW Hang on!)

Oh, gas turned limewater but did not effect dichromate paper.

So that - the limewater tests tells me it could be a carbonate and it doesn't affect dichromate paper, so I can cancel out at the moment a sulphate.

(JEW Which one?)

the SO_4^{2-}

(JEW Can you?)

Oh this being

(JEW Treatment with acid)

I see (4) now (4) I'll stick with carbonate and sulphate - I don't know why I keep on sulphate! Probably 'cause you prompted me.

(JEW If you think of the nitric acid as a substitute for hydrochloric acid)

Yes

(JEW Then what are you likely to get from hydrochloric effervescence?)

A chloric gas no?

(JEW No! according to that)

you could - well carbonate, you'll get a carbonate

(JEW, I agree)

It didn't affect the dichromate paper

(JEW Therefore it's not)

It's not a sulphite - yes - it couldn't be a sulphate either that turns dichromate paper green - cancel out the sulphite sulphate and stick with carbonate.

(JEW Rightyho, now, on your first test all you've got out of it, Does the fact that its a colourless solution give you anything to go on?)

Erm, it won't be the transition metals? Erm it could be iron er it can't be iron or copper 'cause they give coloured solutions and its colourless solution - I should think it could be a carbonate - metals - they're usually insoluble this is an acid though, it could have dissolved in it - erm - I

don't think its any of the transition metals so it could be probably calcium or lead.

(JEW O.K.. We've explored that one fairly well. Now this person decides to add dilute sulphuric acid to it)

White ppt. was obtained insoluble in hot ammonium sulphate solution - erm - it could be calcium from this test I think, because that gives you - no - insoluble in hot - gives a white ppt. but insoluble in hot ammonium sulphate solution, so that doesn't fit the calcium - very well - erm - erm - let me think - hot ammonium sulphate solution has no effect - there's no gases given off - um - can't be a nitrate 'cos there's no oily condensate given off - just a precipitate formed. I should think I should think its probably calcium but its not that soluble.

(JEW It doesn't ring true does it?)

No it doesn't ring true

(JEW O.K. Let's move on)

Now - this now soluble in hot water concentrated now this could be an SO_3 a sulphate, so it could be a sulphate and a carbonate and not a transition metal - soluble in hot - if it was insoluble it would probably be the sulphate as I think its probably the sulphate but then the sulphate didn't give a - a have any effect oh! it didn't effect the dichromate paper earlier on. No? It could be a sulphate, carbonate, er I'M not sure about the calcium.

(JEW O.K. So you're a little unhappy about both)

Yes

(JEW O.K.)

Soluble in excess sodium hydroxide now if its soluble, now it could be zinc or lead, lead II - now - now you would - you got a white ppt. with the acid - a white ppt. with the alkali

soluble - its soluble in excess alkali - it probably is a zinc or lead. But then, the zinc is a transition metal - I ruled that out before so but it doesn't give colours as much as the others - ah now it could be a zinc or a lead II - but when it was heated - but it hasn't been heated, um - I don't think I can rule out lead erm -

(JEW Like the analyst you're in a bit of a perplexed state - so lets see if the final test gives you any help!)

This is with the solid in nitric acid - no - just with the solid.

(JEW Heat the mixture of these two salts up)

A sample of the mixture was heated strongly - the solid melted, so its got a molecular kind of structure - gave off brown fumes, that makes me think of nitrate - and when it had cooled turned a yellow solid ah! lead! - doesn't say, it went red when it was not though - so it can't be zinc then because it would be white when cold, so I think I can rule out zinc, lead turns yellow when it was cold - it could be lead then, lead II, nut there's nitrate given off - oh! so its probably nitrogen oh! and a lead, I think there's probably a lead II, with erm carbonate, sulphite, not sulphate and erm a nitrate. There's quite a lot there! erm cooled? They're not all positive tests but they don't completely fit - they half, but would lead give a white ppt. with sulphuric acid? Carbonate sulphite and nitrate - I'm a bit unsure, I should think. I'll stick with lead, nitrate, carbonate and sulphate, could nitrate be a ligand from the lead? I don't know, surrounded by the lead so.

(5) An off white powder - slightly lumpy (laughs) oh dear! (more laughter) - a white powder - oh well I cancel out the transition metals except for zinc and erm its a solid - slightly lumpy. I'm sticking with the non-transition metals and zinc at the moment.

(JEW Can't make anything of the lumps?)

No! (laughs) its a solid.

E is partly soluble - now! the temperature dropped - the supernatant liquid was colourless - the temperature dropped - is taking energy in - endothermic reaction occurring? the solution was colourless - if it was colourless then I can rule out iron and copper, I can rule out copper and iron - yes they're transition metals - erm, it was partly soluble so it would be a carbonate, but that's completely insoluble, it could be a carbonate and erm it could be lead, a lead compound which is insoluble - it won't be, lead nitrate, cos then it would be soluble. It could be a lead compound and no transition metals - could be zinc - I'll stick with a lead compound, the halogens or the alkalis.

E melts boils and solidifies - gives a white vapour which partially condenses, the white vapour? could it be - well if its - white vapour.

(JEW Use your intelligence as well as your analysis sheet here!)

Yes! white vapour - partially condenses - it does not smell - litmus paper red - moist litmus paper red - solid residues is white - I think it could be acidic - it won't be nitrate cos its not brown fumes, its a white vapour - could be a chloride, but then it didn't give a smell. The carbonate CO_2 isn't a white vapour I don't think - it wouldn't condense probably is a sulphate or a - sulphite! Erm solid residue is white - that will be the oxide - melts boils and then solidifies. Er when it solidifies its probably is the oxide which is being formed - the gas being given off when it boils - so I should think - I'll cancel out transition metals - zinc oxide? it could be zinc oxide, it could be zinc could be lead.

I think its a sulphate or sulphite - condense - erm - turns moist litmus paper red - its an acidic - I'm cancelling out nitrate at the moment - and chloride because it would smell then and the nitrate would give out nitrogen dioxide from the NO_3^- . I haven't tested it for carbon dioxide - um! it could be at the moment sulphate or sulphide, sulphite - I'll stick with the non-halogens and zinc.

(JEW O.K.)

Cold acid warmed - now a smell's given off this time! This gas turns moist - now - then that would tell me could be a sulphite - sulphate, and, with cold and so the SO_3^{2-} , the sulphite, needs to be warmed too and if it was the SO_4^{2-} , sulphate, if sulphur dioxide was being given off you would tell from the smell, but it wouldn't need heat to make it evolved, that's sulphate, so it could be a sulphite - that needs to be warmed a pungent smell is evolved so that would turn it red - and it also turns potassium dichromate too - the solution remaining is colourless - so I think it is a sulphite at the moment, but I don't know where the white vapour - the white vapour didn't give a smell before - its a colourless solution pungent white fumes? That - now - it could be er hydrogen chloride - a chloride present and it does turn silver, silver nitrate - drop milky yes - and hydrogen chloride would do that - so there's probably a chloride present as well as the sulphite. I'm not sure on the actual anion-action sorry.

(JEW O.K.)

Dilute sodium hydroxide - white ppt insoluble in excess - now this could be calcium now, which was - it could be an alkali metal, probably diluted hydrochloric acid - I should think its a calcium - could it be erm calcium sulphate/chloride,

calcium chloride sulphite at this stage. Ammonium hydroxide solution - no action - can't be copper II then! Well it won't be copper II before as it would give a colour earlier on in the test so - I rule out copper II - I ruled it out before - so I'll stick with calcium nitrate - calcium sulphite and chloride at the moment. No action with ferrocyanate - then I'll rule out - I can definitely rule out copper II at any rate and FeIII. I can rule out too, so its not those two - its not a transition metal anyway - I'm sticking with calcium sulphite chloride at the moment.

With barium chloride - almost soluble now if its almost, that would - if its almost soluble then it could agree with the er sulphite - because it does give a white ppt but it doesn't give a very soluble - so I'll stick with sulphite.

Silver nitrate solution - now - chunky white (laughs) ppt - oh dear - mutters - so its soluble in er in er ammonium hydroxide solution - it is a white ppt and in light begins to go grey - so yes there is a chloride present - definitely a chloride present.

White ppt soluble in hot ammonium sulphate - solution of E erm - chloride? acid, could be calcium yes - thats a test for calcium - now I think it is calcium sulphite and chloride.

Think thats what I said before - I stick with it - those three.

Caistor Tapes 'L'

(2) Um - its pale green crystals - so that would suggest that, that um its a coloured compound - which could be iron or copper, and um in water its coloured again this would suggest these two again, which it is, so its probably an iron or copper compound, and on heating - brown black colour is produced which is iron or copper again. Um the white fumes could be chloride or something like that, but no - um - it wouldn't be - this probably would be sulphur dioxide which would suggest that a sulphite - sulphate ions present - um, but um if could well be ammonium one of the ions could well be ammonium because of the change from blue to red again on heating again and on adding dilute hydrochloric acid um there is a colourless solution obtained. No gases are given off so this would rule out any sulphur compounds - or carbon dioxide. With concentrated sulphuric acid; if there's no action - this rules out also a chloride or a nitrate. So the two anions left could be ammonium and - thats the only one left it could be - so the anion's likely to be ammonium.

With sodium hydroxide added - um there's a green ppt - pungent smell and a green ppt usually indicates iron II so the two ions at present are ammonium and iron II. The red litmus going blue again indicates ammonium present - hexacyanoferrate going medium blue um, doesn't really indicate whether the ion's iron II or III and with no action of K.I that rules out any chance of it being um chloride again.

The $BaCl_2$ goes with a white ppt which is insoluble suggests a sulphate - so that also seems to be present.

And silver nitrate shows no action - so - silver - no chloride present, but er test 8 (KI) was a test for lead or copper so copper does not seem to be in so this leaves just

er the ions, iron II ammonium and perhaps sulphate.

(JEW Prompt)

The sodium hydroxide test showed there was iron II present but not iron III or the ppt would have been red brown, so we can rule out the iron III so that would just about leave just iron II and the hydrochloric acid test and the colourless solution - um - with no apparent gas being given off. Which would rule out any sulphur or sulphate - which leaves just the salt as being iron II ammonium.

Hydrochloric acid doesn't really indicate that there's no sulphate because the dichromate test isn't used so there could be gas given off which hasn't been tested from its, that would leave the sulphate, sulphate IV but it rules out the other sulphate.

(JEW It has ruled out sulphate IV but it hasn't ruled out $\text{SO}_4^{=}$ VI)

(JEW There is evidence in test III that you are getting dichromate going green)

Oh sorry, its erm you get er sulphate VI from action of barium chloride as well as from dichromate test going green in question 3, so that indicates that the sulphate VI could be there as well.

(3) The appearance of solid C is that its a turquoise powder and again this would suggest iron or copper as these are both coloured solutions or compounds. When there is water added - there's a blue solution and this is an insoluble solution because - there is a solid residue left at the bottom so um - this could be an iron or copper compound again perhaps a carbonate as well - um when heated the solid is brown or black so that's again iron or copper, there's nothing definite about that and erm, the moist litmus is turned red - this suggests an acidic which will be the anion - which tends to lead us to

ammonium - um when there is dilute hydrochloric acid added um, the gas turned limewater milky which would suggest carbon dioxide unless there is sulphate IV present which would react also with the limewater and give an improper result - but if the dichromate paper or the litmus paper are not affected and there was no detectable smell, this would rule out any sulphate, sulphate IV or VI from being present - when the concentrated sulphuric acid was added, um there was no smell detected but there was an effervescence which suggests a chloride and rules out a nitrate um and there is no further heat change occur - so there will be a chloride present. So the anions left are chloride carbonate and ammonium, but ammonium salts are soluble and er this salt was insoluble in water, so that rules out the ammonium salts - and leaves the carbonates and chlorides. There doesn't seem to be any way in which either of these could be ruled out. As for the cations, there is copper II and iron which could be present - testing with heat would either, indicate either of these two still left.

(JEW reminds him that ammonium is a cation and he has five ions)
I don't think the ammoniums there, the action of heat um where fumes were given off that turned litmus red.

(JEW but what sort of a gas is ammonia?)

Ammonia turns red litmus blue doesn't it?- so ammonium out.
Eventually prompted to answer by elimination.

(4) Use of nitric acid is to test for the presence of chloride which er requires silver nitrate added - there's no mention of this - but there's an effervescence which means that the nitrate's reacted with one of the cations - um the solid and so the anion chloride can be ruled out. With sulphuric acid being added, there is a white precipitate formed.

(JEW draws his attention to overlooked data)

Well - um - um - gas turned limewater milky but didn't affect dichromate paper, so this suggests that there is no sulphate there as it would have affected the dichromate paper and leaves limewater? carbonate which would have affected the limewater.

(JEW which sulphate?)

So that's SO_3^{2-} , chloride ruled out so one of the anions is a carbonate - but the sulphuric acid test gives a white ppt formed which is insoluble in hot ammonium sulphate solution - er - I'll go back to that later. The barium chloride, the white ppt indicates sulphate present and if this is soluble it indicates sulphate IV but this is when reacted with hydrochloric acid as it could be that um - the - something from the hydrochloric acid reacts and not the sulphate IV which might be suggested. Um - the sodium hydroxide gives off a white ppt - which is soluble in excess alkali - this indicates that the cation could be zinc or lead and rules out calcium and with the heating of the solid melted and gave off brown fumes this would indicate that there was a nitrate present and is this solid when it was melted, cooled down to form a yellow solid, this would indicate that one of the cations could be lead because of its colour when it was cold. Which would be lead oxide. Going back to the sulphuric acid, there was a white ppt formed - um which is insoluble in hot ammonium sulphate solution, there was no gas given off but if there had been this might have reacted with the ammonium sulphate or - so that nitrate could have been present or had reacted, so that could still be there and the chloride could still be there - the barium chloride gave a white ppt which was soluble in concentrated hydrochloric acid whereas (1) had suggested there was no effect on the dichromate paper,

but gives no mention of any bad smell being given off so there might have been, which might have been hydrogen sulphide, given off but hadn't been mentioned, so it still indicates that sulphate IV might be present and the barium chloride test rules out sulphate VI, um - when - when solid D was tested with the dilute nitric acid, no silver nitrate was added, so still don't really know whether a chloride was there, but the test on the sulphuric acid could rule out - could rule this out because hydrogen chloride should have been evolved but it wasn't and er hydrogen chloride turns silver nitrate milky - there was an effervescence in nitric acid - this could lead to a chloride being there still so we've still got a nitrate, carbonate, chloride and sulphate IV then.

(JEW reminds him of two salt limit)

Nitrate has to be there, we'll leave that one in because heating the solid, there's no indication that any of the others could give off any brown fumes - long gap - if the white ppt was insoluble in hot ammonium sulphate - if it had been soluble - um - this would suggest - um - the carbonate could be there, seems to be there and test 1 rules out any sulphate IV reacting with it because of the use of the dichromate paper.

(JEW leads again)

If there's a white ppt. rules out iron or copper and a white ppt would be zinc or lead from testing with sodium hydroxide

(JEW lead salts?)

Um - they are insoluble except for the nitrate - so this rules out a lead nitrate, because the ppt insoluble and if the nitrate is soluble its not lead nitrate.

(JEW Assume it is lead nitrate - what happens when you add BaCl_2 to lead nitrate?)

Barium nitrate and lead chloride.

(JEW Is lead chloride soluble?)

Yes.

(JEW Then he eventually gets the idea that the ppt is lead chloride)

(5) Appearance is an off white powder so this could rule out iron and copper because of these two ions are usually coloured. When added - when water was added there was a colourless liquid formed which also means that iron or copper aren't going to be present because they would have coloured solutions. If the solution was colourless this would mean that the ion was soluble so, nitrates and ammonium salts would be present or at least partially soluble which would mean that - um carbonate could also be there as well as nitrate as an anion.

Um, the temperature dropped - I'll leave that - both the action of heat - um - compound melts um boils and acidifies again and gives off an off white vapour, which partly, partially condenses, so it's not likely to be a nitrate formed because NO_2 would be given off and this would be easily recognised, recognisable as brown fumes and if the vapour turned moist litmus paper blue, moist blue litmus paper red rather, um this could indicate that there was ammonium there if, because the ammonium would have turned litmus paper blue, but as it already blue, we don't know if it would turn red again.

The temperature dropped too, doesn't seem to be very important because we're not told any information about if the temperature drops, so that can be ruled out and the lumpiness of the solid could also be ruled out.

(3) Partial condensation of the vapour doesn't give much away as to the compound. If the solid residue is white though,

this could indicate zinc though because when this is heated after melt, melting it goes solid again which is white, so this residue left which would be solid which is white indicates zinc. Um, when hydrochloric acid is added, there's no action with the cold acid but the hydrochloric acid would need to be warmed in any case, so this doesn't give much away. When it's warmed there is a pungent smell given off, which would suggest a hydrogen sulphide. If this turns the litmus paper blue - this doesn't indicate anything further - sorry! it turns the litmus paper red. This doesn't indicate that this could be a sulphate IV, sulphate VI or any carbonate, but if it turns the potassium dichromate paper green, it would suggest a sulphate IV if sulphur dioxide was given off as well as hydrogen sulphide.

There doesn't seem to be anything about limewater so I don't know if the carbonates present. And again the remaining solutions colourless and we already know that zinc or copper be present, so that enhances that. The concentrated sulphuric acid gives effervescence immediately - with pungent white fumes which are red would indicate hydrogen chloride being given off, which is acid acidic, so would give off a red colour and potassium dichromate paper was green this might also suggest sulphur dioxide being given off, but this really doesn't fit in with the sulphuric acid -and - but um adding the silver nitrate doesn't really add anything further cos this would probably react with the sulphuric acid to give nitric acid and so would sulphate, so this doesn't give anything further.

And um, the potassium dichromate paper going green would indicate that um sulphate was being given off but this could be from the sulphuric acid and not from the sulphate VI ion.

With sodium hydroxide solution being added, there was a white

ppt which is insoluble in excess sodium hydroxide solution so this would indicate that calcium was there unless - no - just indicate that calcium was present.

Ammonium hydroxide - there's no solution so this rules out copper again, but the colour or the appearance of the solid already rules this out. The hexacyanoferrate there was no action so this doesn't give us any clue - but it does rule out most of the cations except calcium which seems to be present from adding of sodium hydroxide and it rules out ZED LINC Copper and both Ions. For the barium chloride there is a white ppt which was soluble in hot hydrochloric acid, so this rules out sulphate VI which would be insoluble and indicates sulphate IV which we'd already found from the hydrochloric acid. With the silver nitrate if there's a chunky white ppt this indicates, a white ppt, indicates a chloride present so this, and em, and if this dissolves this means the solution's soluble in the ammonium hydroxide solution which is added which again indicates chloride. The residual left begins to go grey this would be something to be with the silver in the solution - would not lead on to any more about the ions present - um - the dilute sulphuric acid added to an aqueous solution gives a white ppt - which is soluble in hot ammonium sulphate and this em again leads us to calcium which has already been established as the cation and the only cation which can be in the solid E, though there could be, there could have been zinc there because the solid residue was white but this could have been the calcium, this rules out the zinc if this is so.

Ammonium could be there because of the action of litmus, but the sodium hydroxide test does not fully support this. Calcium chloride - sulphate IV.

Caistor Tapes 'M'

(2) Well, coloured salts of em, lead and copper are usually no, iron and copper are coloured, so it could be iron and copper. Solubility in water soluble giving yellowy green solution, yes well er, could be nitrate or ammonium - its unlikely to be carbonate or a lead salt, that would indicate copper but Action of heat - this solid turns white, then brown black. Gives off pungent white fumes which turn moist blue litmus red and dichromate paper green, mm. White then brown black. The black would indicate copper or maybe iron, the brown, that could be iron or copper again. Blue litmus red, mm. litmus paper goes red, sometimes with ammonia, but very rarely. Protracted heating the type of smell changes mm. I'm not too sure about that. White fumes. The white fumes what could they be? Well? I'll leave that for the minute. Action of dilute hydrochloric acid, a colourless solution is obtained - doesn't say anything about gas evolving, but I don't know about that, haven't learned much from there apart from the solid will dissolve in hydrochloric acid. Concentrated sulphuric acid to solid. There is no action apart from a slight dissolution - well, I don't think that tells me much. Well I'll have to think about those - go back to number three, solid turns white, then brown black, that's copper or iron. I think - well suppose the blue litmus turning red could indicate ammonia but I'm not too sure about that, its not, well, probably not, sulphur dioxide indicating a sulphate er, no brown fumes so that a nitrates unlikely. Go on, dilute sodium hydroxide solution? Dirty green precipitate, the pungent smell on warming, red litmus, moist, goes blue. Well, looking down my list of things - suppose - dirty green precipitate, doesn't seem to be er mentioned there, so I don't think that

tells me too much, red litmus goes blue, that would indicate an alkali and the alkali - ah - zinc or lead. I don't think it's either of those - any case they have white precipitates soluble in excess alkali - ah - here we are, red litmus goes blue on ammonium, ah well, that backs up the first theory that might be ammonium present so it could be ammonium, iron or copper. Er, right now - hexacyanoferrate, medium blue ppt - ah, well that shows iron either iron II or iron III, now, how can you differentiate between those? Come back to that later. Potassium iodide solution. No action - well er - that rules out lead - doesn't tell us a lot! Barium chloride solution. White precipitate, now barium chloride, white precipitate insoluble in hot concentrated hydrochloric acid - um well! That indicates a sulphate - that rather - so its probably ammonium and sulphate now - right the last one, silver nitrate solution. No action in dilute nitric acid - ah, well, that rules out a chloride, that doesn't really tell us anything. So we have possible ammonia, possible copper, what did we say iron and possible whats the last one?

(JEW Plays back tape to recap)

It looks like its copper iron, sulphate and ammonia. Well, we'll just have a look back at the first few tests. Appearance - pale green crystals - now - suppose the colour could indicate copper and iron - well we thought copper and iron were there anyway. Solubility in water? Soluble giving yellowy-green solution - now - ammonia salts are soluble um - lead salts have a tendency to be insoluble but really we want iron.

Well it backs up the ammonia theory anyway.

Now - action of heat. White then brown-black. Well that's iron and copper - well the white fumes are probably ammonium - on protracted heat the type of smell changes and the red litmus

reverts to blue - well I think that's ammonia so I'll say definitely ammonia.

Dichromate paper green - sulphate - yes its probably sulphate and ammonia. concentrated sulphuric acid - no action apart from a slight dissolution - lets think - concentrated sulphuric acid - well just really rules out nitrates and chlorides.

Dilute sodium hydroxide solution, Well I suppose - dirty green ppt - well? I suppose the green could be described as "jelly like" so iron - yes - seems to be iron. Red litmus goes blue, that's ammonia, so we have ammonia, sulphate and iron. Right! the hexacyanoferrate, as I said before medium blue doesn't discriminate between the iron II and iron III. Potassium iodide - hang on a minute! There's no action - that rules out copper or could rule out copper - that's interesting! Now, barium chloride - white ppt - insoluble, well that's a sulphate and ammonium - it looks like it! Silver nitrate - that just rules out the chloride so again we're stuck with an iron, plus ammonia, iron, ammonia and probably sulphate.

(3) First, appearance. Turquoise powder - yes well, again that could be the coloured salts of iron and copper. Action of water - after being shaken with water it settles out to leave a solid residue at the bottom of a blue solution. Ah! now, iron and copper salts are coloured solutions as well, but solid residue at the bottom of a blue solution, ah well that could be a? two salt? erm - could be two separate substances, looks very likely - action of heat on solid turned brown black - ah! now that's copper II and iron. Yes iron and copper, that seems very strong. Moist litmus paper was turned red, but there was no visible fumes, well the residue indicates an acid being given off, suppose a small amount acid -

could give off - fumes - invisible fumes.

Action of dilute hydrochloric acid on the solid there was an immediate effervescence - shows it gives a good reaction! Gas turned limewater milky - that's carbon dioxide! Muttter - litmus paper nor dichromate paper affected by the gas, nor was there any detectable smell. Well carbon dioxide indicates a carbonate and I don't suppose that would turn the papers either acid or alkaline, and probably wouldn't smell either so it could quite probably be a carbonate. Action of concentrated sulphuric acid, another immediate effervescence but no smell - well! When heated - no further changes occurred, that seems to rule out the nitrate, and the chloride, um well that's interesting because the turquoise the er, blue solution could have been copper chloride. Have to look back - action of water again - settles out - to leave a solid residue at the bottom, so one of them's soluble - now that could be a lead salt or a carbonate. Yes! a carbonate we have carbon dioxide, so its probably a carbonate. Brown-black, lead and copper, iron and copper, I mean, oh, well that's interesting doesn't tell me much else though! Moist litmus paper's turned red - well, let's see - I don't suppose that's ammonium? It's very unlikely - an acid is given off? Now! Think! erm, I can't see anything reacting with water to give off acid fumes - apart from - no - I don't know.

Action of heat on solid - no! I don't know about that one! Well action of dilute hydrochloric acid on solid - um - immediate effervescence - gas turned limewater milky - well that's definitely a carbonate then! Yes there was no detectable smell - that seems to back up the carbonate. Action of concentrated sulphuric acid no smell and no changes well, as we said, that rules out the chloride and the nitrate, so I think carbonate more than likely - definitely carbonate! Back

to the dilute hydrochloric acid - well, it rules out sulphate VI and sulphide. Action of heat on solid - moist litmus paper turns red. Ah, now, what could we get out of that? Ah, see if we can rule out anything - well nitrates again - um, not ammonia, no zinc, no lead, the copper is indicated by the appearance, copper carbonate but there's probably something else there as well!

Let's take it from the beginning again.

Um, Solid residue at the bottom really does show its probably something else. Action of heat solid turns brown black - well yes! copper could be iron - there's nothing to rule out iron! Moist litmus paper - was turned red - acid - what could give out an acid with no fumes? It's not HCl, because we've ruled out chloride, we've ruled out the nitrates, suppose there's a sulphate now - maybe it is a sulphate - after all, maybe I was wrong to discount a sulphate VI. Um verylikely so something sulphate? Copper sulphate! of course! Yes and um the insoluble residue iron or copper carbonate.

(4) Right - um - nitric acid effervescence to give colourless solution - there's no mention of a white precipitate there - so chloride appears to be out for a start - gas turns limewater milky but did not affect dichromate paper well the gas is probably carbon dioxide, no therefore probably a carbonate, but a bit early to tell yet, the solution - a white precipitate was obtained when dilute sulphuric acid was added to it, insoluble in hot ammonium sulphate solution. White ppt soluble in hot ammonium sulphate solution, well that does seem to indicate calcium - first of all - so calcium could be put down as a very likely possibility. Barium chloride produced a white ppt soluble in hot concentrated hydrochloric acid - sulphate IV

or sulphite - that's interesting - calcium carbonate and sulphite bear these in mind. Sodium hydroxide - produced a white ppt soluble in excess sodium hydroxide - this is an alkali - this leaves zinc and lead. So if I go back (re-listens to tape). Right with zinc or lead, carbonate, sulphite and calcium - right last test. Solid melted, gave off brown fumes and when it had cooled turned to a yellow solid. Ah! now brown fumes - that's a nitrate, unfortunately - cools down to a yellow solid - ah well that's lead - so two metals are lead and calcium and then as the other substance we have lets think - carbonate - um - sulphite and nitrate. Interesting - lets have a look at that! well, the gas turned limewater milky! but did not effect dichromate paper. Oh well, I suppose the er carbon dioxide - does seem to give off carbon dioxide, I wonder if the nitric acid? No I can't see that producing, its something else - er lets see, dilute sulphuric acid - white ppt was obtained, insoluble in hot ammonium sulphate solution - what am I talking about? Calcium's soluble, this is insoluble in hot ammonium sulphate! Oh - that doesn't do us a lot of good. Ah - shows it can't be calcium. Barium chloride - white ppt soluble, that seems to indicate the sulphite - now moving on - sodium hydroxide gives a white ppt white ppt - soluble in excess alkali - I did say it was zinc, sorry lead, lead is definite. Brown fumes, I take it now she didn't heat the erm the solid after it had been treated with dilute nitric acid. Well?

(JEW confirms that the test was done on the original mixture)

(Replays again)

Let's see, I'm getting a bit muddled up here, I have carbonate, lead, sulphite, calcium and nitrate. Right - I'm not too sure - I suppose that nitrate - is pretty strong evidence -

but ... let's think. How did we rule out calcium - ah yes! the insoluble reaction to ammonium sulphate and the sodium hydroxide white ppt soluble in excess which indicates zinc or lead. It could rule out calcium, but maybe there is calcium in there after all! Now dilute sulphuric acid insoluble in hot ammonium sulphate solution - well - I suppose this could be a result of, the the er was it lead, yes, the lead. So, yes, I'll stick calcium back in there. Calcium lead and carbonate, nitrate and sulphite.

Just a minute. Heating brown fumes, it doesn't say anything about carbon dioxide then, just when you put on the nitric acid. Nitric acid? Still not too sure there - about carbon dioxide - rather tricky. See if we can rule out the sulphite in any way, maybe we can. Dilute nitric acid dissolve with effervescence to give a colourless solution - well - I don't know about - gas turns limewater milky, but doesn't affect dichromate paper. Sulphur dioxide - shows its not sulphate VI - it rules out the sulphite - dichromate is not affected. In that case its lead and carbonate and calcium and nitrate.

(5) Appearance - off white colour - slightly lumpy - iron and copper produce coloured solutions and are coloured.

Well, that really doesn't tell me anything! E was partially soluble, the temperature dropped and the super

(JEW translates)

yes, the liquid was colourless - now well, iron and copper don't usually produce colourless salts, but well, they could do. Now, the action of heat. E melts, boils and (matters) gives off a white vapour which partially condenses. Ah that could mean there's water in it! The vapour turns moist blue litmus red - that indicates an acid - solid residue is white um - let's think - zinc is white when cold - yes - zinc. Action of dilute hydrochloric action with cold acid, but when it is

warmed, that's not unusual a pung - pungent smell is evolved -
Ah! now - bad egg smell, I suppose that is, hydrogen sulphide.
Now that's interesting, hydrogen sulphide! So a sulphite/sulphide,
yes - gas turns moist blue litmus paper red - mm - that
indicates acid - potassium dichromate green - um potassium
dichromate green? there isn't any potassium dichromate on
that particular acid test - yes there is! sorry! Sulphite,
mm, action of concentrated sulphuric acid. Immediate effervescence
well - effervescence, pungent white fumes turn moist blue litmus
red - well pungent - hydrogen sulphide again, or maybe a choking
gas which fumes in air. Um - now - the fumes turn slow nitrate
acidified with dilute nitric acid, drop milky. Now, well,
chloride, yes that does indicate a chloride. Sodium hydroxide
solution. white ppt insoluble in excess sodium hydroxide -
ah! does show calcium, maybe - now, the ammonium hydroxide
no action. Well seems to rule out the copper II anyway!
Now potassium hexacyanoferrate, no action again so, um, seems
to indicate there's ni iron II, III no copper II, no zinc
and no lead. That helps rule out quite a few, if that's right.
Now, Barium chloride, a white ppt. completely soluble, almost,
take that to mean "soluble" in hot concentrated hydrochloric
acid - well that's a sulphite, now! Just recap - see if was a
sulphite I obtained earlier on (replays). Definitely a
sulphite then! well unfortunately, I've forgotten what else
I've decided -looking back again, definitely a sulphite,
solubility in water well, apart from the lead nitrate, that
seems to rule out lead, as I think its a sulphite, it's
probably not a lead salt. Um, carbonates, we're already decided
its a sulphite. The action of heat - um white vapour partially
condenses, vapour turns moist blue litmus paper red - um solid
residue is white - well, just shows there's an acid given off.
Probably sulphuric acid.

Action of dilute hydrochloric acid - um, pungent smell is evolved hydrogen sulphide yes and H_2SO_4 as well probably. Potassium dichromate paper green well, any other acid tests. Sulphite yes, definitely a sulphite, question is, which metal goes with it? Action of concentrated sulphuric acid - now - chloride - suppose a chloride could be there. Sodium hydroxide, white ppt insoluble - Ah, that's a calcium, I'd forgotten about that so that tends to give us a calcium, not definite proof, but pretty strong. Ammonium hydroxide - no action - rules out copper, right - hexacyanoferrate, no action - rules out the irons, copper zinc and lead, calcium, not calcium. I'm reading down the page, so its probably calcium and sulphite, question is where did the sulphide and chloride go? Well the sulphide could have been formed by decomposition which rules out a chloride? Barium chloride solution? That seems to indicate sulphite.

(JEW reminds him he hasn't used test 10 and 11)

Silver nitrate solution - chunky white ppt - yes?

Yes mm, well that means its a chloride.

Dilute sulphuric acid? Soluble yes that's calcium, yes calcium chloride, what about the sulphite? Nothing for it but to go back and check again. Now, appearance.

(JEW draws attention to test 4)

Pungent smell that could indicate anything really - um that case the sulphide is not quite so definite. Calcium chloride - check again - appearance - no help. Solubility in water, soluble, that ties in with most of the chlorides, action of heat - white vapour which partly condenses - that's probably water, blue litmus red - hydrogen chloride, solid residue is white.

Action of dilute hydrochloric acid, I suppose the HCl gives

off the pungent smell - again we got HCl given off. Potassium dichromate green - sulphur dioxide - now - I suppose its sulphite, sulphite as well as chloride in there.

Concentrated sulphuric acid, pungent white fumes that's the HCl. given off and potassium dichromate paper green - potassium dichromate green - sulphate?

Sodium hydroxide solution - white ppt insoluble calcium, as before. Ammonium hydroxide - leaves copper out. Potassium Hexacyanoferrate - rules out the rest of the metals. Barium chloride almost completely soluble. Well that shows a sulphite unfortunately.

(JEW why unfortunately?)

Ah, suppose its calcium, calcium sulphite, calcium chloride.

Caistor Tapes 'N'

(2) Well the appearance is a pale green crystals - which the green colour might indicate some copper of some description, copper II or possibly no - copper II. The solubility, it is soluble in water, and gives a yellow green solution um - this also often goes green when there is copper present (21). When the er salt is heated er a black-brown er solid is er produced erm - that also would be copper II erm but the brown colour could also be iron. Erm gives off white fumes which turn moist blue litmus paper red and dichromate paper green. Er dichromate paper green - turns green if a sulphate, sulphate VI is present and er the litmus red er means it is acidic and er so it is probably an acid it'll be an acid of some description (12).

Er after it is heated for a time the erm smell changes and er red goes to blue again which probably er indicates that some of the salt er has been removed. The acidic er salt So, so far we have copper and er er sulphate (VI) at present.

(18). A colourless solution is obtained with er hydrochloric acid and erm the er, this rules out the sulphite which would be evolved er as a gas erm carbonate would also be evolved as a gas, but er a solution is formed (18).

With er concentrated sulphuric acid erm, there is hardly any reaction, but if er chloride was present, then, gas, gas fumes would be evolved and erm hydrogen er chloride could also be evolved, as a gas er - it says that there is no action and so that rules out the presence of a nitrate in the solution, in the salt (23).

Er with erm sodium, dilute sodium hydroxide, green ppt is formed er this could be the copper er, as before, its warmed and er its pungent smell evolves well er ammonium er smells

when its er heated and probably the ammonia will be er there.
Er the red litmus goes blue which will indicate an alkali
but the ammonia is an acid.

(JEW corrects)

Sorry, all which probably er strengthens the fact that ammonium
is present. So far we have copper, sulphite, because of the
dichromate paper.

(JEW you said sulphate)

N checks back - Sulphate VI is present, but er, if sulphate VI
was present then a white ppt would be sorry thats the
wrong one.

Er medium blue ppt is formed with er potassium hexacyanoferrate
and er this would indicate, probably wouldn't indicate iron III
cos that's a deep blue ppt em - well it er - doesn't really
tell me all that much, I don't think though!

Erm potassium iodide solution, then there's no action at all,
and if there was an action there would be a white ppt or a
yellow ppt would be formed and er that would indicate lead
or copper. Er - but, previously I said copper was present,
so er it might be iron because the er heat er of iron also
er turns the salt black when its heated (23).

With barium chloride, the er salt forms a white ppt and er is
insoluble when hot, insoluble in hot concentrated hydrochloric
acid, this er is an indication as sulphate VI is again present
as er a white ppt is formed and er is insoluble in hot
hydrochloric acid (12).

With er silver nitrate solution this is er no action - er -
(10) if er chloride was present then a white ppt would er
be left with the salt. This rules out the chloride. The
er copper er was contradicted by the er potassium iodide test,
so I think it would probably be iron with that salt er - iron

and er sulphate er IV er VI.

(JEW VI is 6)

Yes! The ammonium. I think its probably ammonium iron sulphate VI.

(JEW Which iron II or III?)

The potassium hexacyanoferrate um was a medium blue ppt. On the test sheet iron II forms a light blue ppt, so I think its probably iron II.

(JEW With assistance he then derives more iron II evidence possibly a mixture there of II and III)

(3) Appearance is a turquoise powder, er (14). It's er an insoluble salt, as it well, it's probably, it's insoluble but it might not, some of might be soluble and others not soluble - as it er leaves a solid residue at the bottom and the solution turns - blue, so some of it is er dissolved in the water, but some of the salt isn't. (8). The solid turns brown to black which could indicate copper II or iron and also probably the iron or copper (10). The litmus paper turned red and er if ammonium was present then the litmus would turn blue. Erm, no fumes were visible - er that also er means er that the nitrate V iron, which would turn brown is not present, and er you wouldn't be able to see the carbon dioxide so the carbonate may be present. (13). With er the hydrochloric acid turning the er limewater milky, er carbonate is probably present as carbon dioxide would be evolved. Erm but the chromate and litmus paper were not affected by the gas that came off and er (5) erm there was no er detectable smell and the bad egg smell is typical of sulphide and so that probably isn't present, so that leaves me so far with copper or iron and a carbonate, so far! Erm, with er concentrated sulphuric acid erm, the salt did effervesce er, but no smell was

detected and so that's the sulphide out, again erm and also this eliminates the nitrate as brown fumes would be evolved if this was present.

Erm - so the er ammonium is out as the erm ... as the litmus er turned red and copper or iron er could be present and lead, I think is out because the solid would go yellow if it was heated and it says here that the solid goes brown or black and that no fumes were evolved, so the nitrate V is out but the carbonate erm, er could be there present, because its invisible. So, I think the salt is composed of iron, copper and the carbonate. The sulphate IV isn't present because dichromate paper would be turned green and there's no action on the dichromate paper, with the experiment.

(4) Er the er solid D dissolved, er with nitric acid and er a colourless solution er was given erm and also er, turned limewater milky and dichromate paper was not affected um, dichromate paper, if sulphate IV was present would turn green, and erm turning limewater milky there'll probably be a carbonate - erm. If sulphate IV is present before you can test for the carbonate, you have to add er solid dichromate er in case there's any sulphur dioxide so um? I'll go on to the with dilute sulphuric acid, er a white ppt er was obtained and was insoluble in hot ammonium sulphate. This indicates calcium, to be present um, (20). Er with barium chloride, again a white ppt to be present um, was evolved and er was er soluble in concentrated hydrochloric acid, this indicates sulphate IV er as I said earlier, but I said it wasn't evolved. Oh! (20). Sodium hydroxide. White ppt soluble in excess sodium hydroxide, mm, the white ppt er could indicate zinc or lead, or calcium again, but that would be insoluble, its soluble! er (15) and the er, er salt is er

heated brown fumes are evolved and its turned to a yellow solid. Er, the yellow solid, when it cooled, could indicate - er lead erm, and the brown fumes, would er be nitrate V from the nitrogen dioxide. Er this probably rules out erm, the carbonate, and er the fact that its yellow erm when its er cold, erm rules out er, zinc because that would be yellow, when it was hot and white, er when it was cold. Er er the solid melted er giving off brown fumes - er - er - I would indicate nitrate V and so nitrate and erm lead are possibly present - er - there's two salts!

(JEW reminds him of "runners" carbonate, sulphate, calcium to save time running through the tapes as time was pressing)

With dilute sulphuric acid, it would appear calcium was present, but with er sodium hydroxide, erm, the white ppt could be the zinc soluble in - in the alkali - er - the er sulphate was the other one (he recaps). The barium test - the nitric acid test. The barium test is the er sulphate test but the dilute acid could interfere. So I would be happy with sulphate IV nitrate and lead.

(5) Right, its appearance is off white and slightly lumpy, its partially soluble and er, the liquid is colourless. If its partially soluble then there must be a ppt formed. When its er heated, it melts and then solidifies, it gives off a white vapour which partially condenses, and the vapour turns the blue litmus paper red, and the residue is white so it forms a white solid and er gives off a vapour which er partially condenses. Action with er dilute hydrochloric acid er no action with cold acid but when its warmed a pungent smell is evolved. This could be er - er - chloride? er ammonia? The gas turns litmus paper red and chromate paper green but it also turns litmus paper red - so? that's probably still the sulphate IV (23).

Er with concentrated sulphuric acid, it er effervesces and er pungent white fumes are again er evolved erm - and they turn blue litmus paper red and potassium chromate paper green, mmm if - if the nitrate was present then brown fumes would be detected, and here it says that white fumes are detected, so nitrate V isn't present, and it says that it turns silver nitrate er milky, erm - yes probably it could indicate er chloride present which would account for the pungent smell; er sodium hydroxide a white ppt is again formed, which could indicate zinc, lead II a calcium to be present, but as its insoluble, then erm, it probably means zinc or lead to be present, sorry, calcium present and linc zed, zinc lead (laughs) aren't there because they're soluble in the alkali. The ammonium er hydroxide solution is no action, so copper II is not present and with the potassium hexacyanoferrate there is also er no - er reaction and er if iron III or CuII were present a brown ppt or deep blue ppt would be formed. Er, so that probably strengthens the fact that zinc and lead aren't present - er with barium chloride, er white ppt is formed, which is soluble in hot concentrated sulphur hydrochloric acid er if sulphate was present it would be soluble so sulphate VI is not present. Er, with silver nitrate a white ppt is formed which probably be the chloride as the er, ppt which is left turns grey er, so chloride is present er - with sulphuric acid dilute sulphuric acid, a white ppt which is er soluble in ammonium sulphate is evolved and this strengthens the fact that calcium is present. This is soluble in ammonium sulphate and forms a white ppt so er salt composed of calcium, sulphite and chloride.

Caistor Tapes 'P'

(2) Appearance, pale green crystals, it's a coloured solid so it could be iron or copper, springs to mind and (2) solubility in water, soluble going yellow green solution, so its probably a nitrate or an ammonium salt with again a colour, indicating copper or iron. The action of heat on the solid. Er, white then brown black, er this could indicate copper or iron, and er there seems to be ammonia present due to the white fumes er turn blue litmus red - no - that's wrong, the fumes turn mutter, on protracted heating the type of smell changes and the red litmus reverts to blue, er this is getting confused here. Solid turns white then brown-black indicates iron or copper, then white fumes which turn moist blue litmus red, dichromate paper green indicates sulphur dioxide, and er it mentions smell, the type of smell, it doesn't tell you the sort. It gives off pungent white fumes which turn moist blue litmus red, that's acid and the red litmus reverts to blue, so I'll carry on, I think. Test (4) Action of dilute hydrochloric acid on solid B, colourless solution is obtained - er - this er - will it just er decolourises it - I'm still guessing. I'll carry on to the next one.

Test (5) Concentrated sulphuric acid - there's no action apart from a slight dissolution - er - carry on to the next one. Dil - 6 dilute sodium hydroxide solution - dirty green ppt and a pungent smell on warming pungent smell on warming. Red litmus goes blue - as this seems to indicate hydrogen sulphide - no - hang on - that's the bad egg smell - pungent smell? No! Ammonia! and also indicated by the litmus going blue - alkali fumes and er, the green ppt it er, green ppt could indicate iron II ions. Erm hexacyanoferrate medium blue ppt. Well, light blue's iron II and dark blue is Iron III

could mean both are present or iron II's going to iron III. Potassium iodide solution, No. 8 no action - so that would prove there's no lead there. Barium chloride? erm - that's that would indicate sulphate - no - yes - hang on - yes, sulphate VI. Silver nitrate solution - no action, there's no chloride ions present, so er (recaps) I can't really remember what I've got - but er - I'm not sure about copper? but there doesn't seem to be any real evidence for copper, and er there's iron II ions definitely and probably iron III, er - and there's ammonia present and sulphate VI from test 9. Iron ammonium sulphate.

Problem P3

Appearance, a turquoise powder - so the colour of the solid suggests iron and/or copper present, er which comes to mind.

(2) The action of water, well er, shaken with water - so its insoluble, er the solid residue at the bottom of a blue solution so - er - its partially soluble. Er, colourises water but there's a solid residue. The blue colour indicates copper, and er, I'll go on to the next one, number three. The action of heat on solid; the solid turned brown-black, er, this could indicate copper or iron, copper II or iron. Litmus turning red indicates acidic fume, but there were no visible fumes so - er I'll go on to the next one.

(4) Action of dilute hydrochloric acid, there's an immediate effervescence, the gas turned limewater milky, er - gas turned limewater milky, that may mean er carbon dioxide in there and er - probably, and litmus paper and dichromate paper were not effected by the gas, and no smell, so this could be carbon dioxide and er - action of concentrated sulphuric acid er an immediate effervescence was observed in the cold and no smell was detected - er - the effervescence, but no smell was detected

could mean hydrogen given off, when heated, no further changes were detected - still don't quite know, there's a something carbonate er.

Solid turned brown black, this could indicate copper or iron - erm - turned red, moist litmus paper turned red, but there were no visible fumes, so that er acidic gas is er hydrogen probably - slightly acidic carbon dioxide. I'd say that the substance is copper carbonate.

Problem P4

Solid is treated with dilute nitric acid, er, solid D dissolves - tends to be more soluble and give a colourless solution. So er - that, that indicates to me er that there's probably not copper iron present. Er, the gas turns limewater milky, but did not affect dichromate paper so this could be carbon dioxide - er - did not affect dichromate paper which means sulphite can be ruled out - er I'm thinking of carbonate at the moment and - er 2a, dilute sulphuric acid is added and a white ppt was obtained, well - er - er - I'm not sure about that one, I'll go on to the next.

Er - barium chloride solution was added to the second portion, white ppt soluble in concentrated hot hydrochloric acid was obtained, er - soluble? er - barium chloride - this indicates sulphite and er I've already ruled it out - (nervous laugh) I won't rule it out, I'll keep an open mind I'll go on to the next!

Er - sodium hydroxide solution was added to a third portion and white ppt soluble in excess sodium hydroxide was obtained - er - this indicates zinc or lead probably - er - yes! Finally when it was heated, the solid melted giving off brown fumes and this indicates nitrate. When it had cooled it turned to a yellow solid. Well turning to a yellow solid indicates zinc,

so I'm thinking of zinc, maybe nitrate and er a sulphite and a gas turned limewater milky in no. 1, but did not affect the paper. Er - carbon dioxide indicates a carbonate - no effect on dichromate paper, did not effect dichromate paper - er - its still er stumping me this one and I've got a contradiction and I'm not sure which one to take, it seems to me I have carbonate, nitrate sulphite and zinc. Yes, zinc is right! - I've got it stuck in my head, I think its zinc - er - well - er the dilute sulphuric acid - a white ppt was obtained insoluble in hot ammonium sulphate - er - hot ammonium sulphate - insoluble, this will probably rule out - would this rule out a nitrate calcium soluble - insoluble - so its not calcium, that's a lot of help! (nervous laugh) so - er I'm suspect about test 1, solid dissolves with effervescence to give a colourless solution effervescences, so its probably hydrogen in there, hang on, just a minute, gas given off turns limewater milky, so it should be a carbonate, but then, down here, er think I'll stick with a carbonate. Zinc carbonate and sulphite - this is really getting me stuck - er - the white ppt soluble in hot concentrated sulphuric acid, was obtained - er - I'm unhappy about sulphate and carbonate - if this was an exam - I'd just guess! Zinc and a nitrate, if it is a nitrate - sulphite - white ppt soluble in hot hydrochloric acid - this is soluble in hot hydrochloric acid. Bearing in mind it was treated with dilute nitric acid it would probably be soluble anyway - I might rule out sulphite, because of nitrate solubility so I'll go for carbonate, nitrate and zinc!

Problem P5

Er - off white powder - slightly lumpy - that means its probably not iron or copper. Er solubility in water, E was partly

soluble - er - that means if its soluble its a nitrate or ammonium - er - salt - so I've got the action of heat - melts boils and then solidifies, gives off a white vapour which partially condenses - er vapour turns moist blue litmus red, solid residue is white er - solid residue which is white, could indicate zinc er and er a white vapour given off, er could be er ammonia, but I'm not sure about that, I'll go on to the next one. Erm, dilute hydrochloric acid (reads the data very rapidly) erm, well, warm dilute hydrochloric acid - this could be ammonia, turns moist blue litmus red and potassium dichromate paper green. So er - this could indicate a sulphite, the remaining solution is colourless, which again discounts iron and copper er - concentrated sulphuric acid - pungent white fumes turn moist blue litmus red again er - potassium dichromate, again this indicates - well I don't know it also turns a silver nitrate drop acidifies with nitric acid milky - er this could indicate chloride - er - I'll carry on - 6 - sodium hydroxide, white ppt insoluble in excess sodium hydroxide - er this er sodium hydroxide, soluble in excess sodium hydroxide, this could indicate zinc or lead again, I thought zinc before, so I'm thinking of zinc. Ammonium hydroxide solution - no action - er that means no copper or iron? Barium chloride, white ppt almost completely soluble - er - this indicates a - probably sulphite again. I got that before as well, so thinking of that and silver nitrate to a solution of E in nitric acid, this indicates chloride probably, the resid - yes - the chloride and er - sulphuric acid was added to concentrated aqueous solution - er the white ppt is soluble in hot ammonium sulphate which indicates calcium, I don't think there's lead there - so it could be calcium in, It could be calcium, zinc, sulphite, ammonia er, calcium, zinc, sulphite and ammonia. I think

thats it - Test 10 said chloride so its calcium, zinc, sulphite, chloride and ammonia, probably that's five.

(JEW reminds him the maximum number of ions present is 4)

I'd already gone for the ammonium or sulphite. Sulphite is shown by dilute hydrochloric acid test, and by barium chloride - er - yes - I really haven't any evidence for the ammonia. I was just thinking about - I reject ammonia. The white fumes and solubility attracted me.

Caistor Tapes 'Q'

The solid B is pale green crystals - erm - it could be a salt of iron or copper, copper tends, both iron and copper tend to be greeny. Soluble in water giving yellowy green solution - it - could be a nitrate, nitrates and ammonium salts cos they're both soluble in water, that's O.K.. The action of heat, turns white then brown-black, gives off pungent white fumes, moist - yes - mutters - blue - um - well, the solid turns white and then brown-black, I can't see any information on the paper, but er - turns moist blue litmus red and dichromate green - well, it could be a sulphate because it turns the dichromate paper green, and the moist blue litmus paper - oh, (mutters).

Protracted heating type of smell changes and the red litmus reverts to blue - well - the type of smell changes, the gas could be changes, or - a different type of gas? um - (12) well, could be ammonium because ammonium turns red litmus paper blue, on rare occasions it can go to red again, which means the gas doesn't have to be a different gas, it can be one of the rare occasions where it - um - litmus paper turns red and dichromate goes green. Sulphur dioxide is evolved and sulphate VI is present. I'll move on, its the action of dilute hydrochloric acid on solid B. Colourless solution is obtained um - colourless - it can't be any transition metal - no gases produced. Don't think it'll be a sulphate IV, and um, not a carbonate, cos there's no milky action on limewater and I don't really think its a sulphide - no bad egg smell from hydrogen sulphide. Move on to concentrated sulphuric acid on solid B - No action apart from a slight discolouration - um! (4) Well, there's no action - er, I don't think it will be a nitrate because no oily condensate is observed and no brown fumes are detected - and can't be a chloride because hydrogen chloride isn't evolved and erm - well no fumes which turn silver nitrate V drop milky

are evolved, so its neither chloride nor nitrate.

At the moment it seems like, er copper er sulphate VI and ammonia. Checking back - er the solid turns white then brown-black - I think the white colour could be just maybe the oxidation of it and the brown black residue it leads to copper II or iron and the red brown is again iron or copper. So we've got ammonium, copper II iron and sulphate VI. Move on, to the dilute hyd - sodium hydroxide solution erm - gives a dirty green ppt and a pungent smell on warming, red moist litmus goes blue! Well, pungent smell on warming, well ammonium tends to give a pungent smell and a dirty green ppt - ah again the green jelly like ppt is iron II and er, the gas evolved the pungent gas, which I think is ammonia, turns red moist litmus paper, this again, gives the sign that ammonia is present. This just reinforces the ammonium, move on to the hexacyanoferrate II, potassium ferrocyanide solution - medium blue ppt is given! erm - medium blue ppt - deep blue ppt is iron III er, thought it might be copper but copper is brown ppt! So not really sure about maybe if iron III is deep blue then iron II is medium blue - that's - think we'll move again. Potassium iodide solution - no action, well the two shown up here are lead II and copper II, as there's no action I don't think it would be either lead or copper, and barium chloride solution, white ppt insoluble in hot concentrated hydrochloric acid, well, if we check the barium chloride test - insoluble in hot concentrated hydrochloric acid. Looks as though its the sulphate VI again. White ppt insoluble in hot concentrated hydrochloric acid - matches up with test very well, so we've got sulphate VI. Um, move on to the silver nitrate solution in dilute nitric acid, no action, well if we look at this, it can't be the chloride and the chloride was disproved with the concentrated

sulphuric acid test and er, that's end of the information -
(switches off and recaps)

Having recapped, the ions present are ammonium, um iron II
and sulphite - I'd like to erase the sulphite, I meant the
sulphate VI ion.

Problem Q.3

Problem 3 - the appearance of solid C, solid C is a turquoise
powder - erm - its coloured, could be iron or copper -
turquoise again. Think its either iron or copper. The action
of water when C has been shaken with water it settles out to
leave a solid residue at the bottom of a blue solution - well
its, it looks to be fairly soluble. Think there maybe nitrates
or ammonium salts. I don't think there are any carbonates,
because they're usually insoluble, in water and lead salts
have a tendency to be insoluble except for the nitrate. Could
be the nitrate again. Er, the solid residue? there's maybe
something that doesn't dissolve in the truquoise powder, that
sinks to the bottom and doesn't dissolve, that could be the er,
metal, metal ion. Action of heat on the solid, erm turns
brown-black and moist blue litmus paper turned red, no visible
fumes. Turned brown black, solid turning black could be a
copper II or iron and we've had the copper already, could be a
salt of iron or copper - and we've got the iron again. Moist
litmus paper was turned red and there was no visible fumes.
Moist litmus paper turned red - this could be the ammonium again -
it says on rare occasions it can then go red after the litmus
has gone blue, so far it could be iron, copper and ammonium.
Move on to the action of dilute hydrochloric acid on the solid.
There was an immediate effervescence and the gas turned limewater
milky, well this information leads to carbon dioxide being evolved
gas is evolved immediately, yes! and therefore it could be

a carbonate. And it could be this carbonate of the metal which sunk to the bottom, which was insoluble in the water! Er - yes! Move - neither litmus paper, moist nor dichromate paper were effected by the gas, nor was there any detectable smell. Well litmus paper and dichromate paper, where is it (mutters) carbon dioxide doesn't affect litmus paper and think the dichromate paper shows up the sulphur dioxide. Ah, carbon dioxide won't affect dichromate paper and there was no detectable smell - er - don't think it could be a sulphide, otherwise the gas evolved with a bad egg smell, that would be hydrogen sulphide. Don't think its a sulphide. So we've got carbonate, er iron and copper and ammonium at the moment. Action of concentrated sulphuric acid, an immediate effervescence was observed in the cold, but no smell was detected, well, with no smells and no choking gases, I don't think it could be the chloride erm - no smell was detected - er don't think its a nitrate, no only condensate is observed and no brown fumes are detected. Doesn't say what colour the fumes were - that's the end of the information, so I think er - looking back at the information - ammonium? I think there's certainly a carbonate there, there's two very positive tests for a carbonate, so there's certainly a carbonate. The only information on the ammonium was the litmus going blue and then going red, but ammonium is a very smelly gas and is very pungent and I don't think well there's been no smell at any time in the tests, so I don't think the gas could be ammonia. So it leaves it between copper and iron. Well the solid turned brown black - action of heat on the solid, the solid turned brown black er solid turns black - that's copper II or iron. Solid goes red brown iron or copper! Oh! but again er - I think - recapping over the information the carbonate is

certainly present - its either copper or iron - copper and iron
er I think I'd say it's copper carbonate.

Question Q4

Solid D mixture of two salts - solid D was treated with nitric acid and the solid D dissolved with effervescence to give a colourless solution. The gas turned limewater milky, but did not affect dichromate paper. Well - gave a colourless solution. I don't really think it would be a transition metal if it gave a colourless solution. And the gas turned limewater milky - this generally means that the gas is carbon dioxide, which could mean a carbonate - but did not affect dichromate paper well the dichromate paper removes sulphur dioxide and if it didn't affect the dichromate paper, the sulphate or sulphite ion, I don't think is present. Solid D dissolved with effervescence to give a colourless solution, yes! colourless solution. Well, I'll move on. Solution from 1 was divided into three portions and the following tests carried out on it. Dilute sulphuric acid was added to the first portion - a white ppt was obtained - insoluble in hot ammonium sulphate solution - aah - well - nitric acid - a white ppt was obtained insoluble in hot ammonium sulphate solution, a white ppt insoluble, soluble? in hot insoluble? in hot ammonium sulphate solution. I don't really think we can take anything from the information sheet there er - white ppt (3) H_2SO_4 to HNO_3 plus the ? (12) the ions a white ppt (mutter) (12) erm - (10) cor - this is hard! white ppt is obtained, insoluble in hot ammonium sulphate solution - this - ppt

(JEW if you get stuck - don't let it fester - move on to something else, you might get a clue from what comes later)

When barium chloride solution was added to the second portion, a white ppt soluble in hot concentrated hydrochloric acid was

was obtained - a white ppt - again! soluble in hot concentrated hydrochloric acid was obtained- barium chloride added to the second portion - well - we've dismissed the sulphate, this leaves chloride, nitrate, sulphate, chloride nitrate, sulphate and carbonate a white ppt soluble in hot concentrated hydrochloric acid, HCl - carbonate - phew I wouldn't like to draw anything off the information sheet, not a lot because it's not in - it's not in just a solution, its in a solution made up in dilute nitric acid. Erm, I'll move on, probably I'll pick up something else later on. Sodium hydroxide solution was added to a third portion, a white soluble ppt in excess sodium hydroxide was obtained, phew, mixture of two salts, again a white ppt erm - think, could be a nitrate, could be a carbonate, we've dismissed sulphate IV, sulphide, er - we're left with sulphate VI nitrate, chloride, carbonate. Phew, white ppt soluble in excess sodium hydroxide was obtained, well, if we look at the sodium hydroxide test, white ppt soluble, excess alkali? it could be zinc or lead, lead II, these are cations, so look to the heating of it see if I can match in the heating with the precipitates. Solid melted and gave off brown fumes. When it had cooled, turned to a yellow solid. Er - yellow when cold, is lead, so I think lead cos white ppt soluble in excess alkali is lead II, so I think lead could be one of the ions present. Brown fumes evolved, and nitrate given off, nitrogen dioxide evolved, therefore nitrate V present, could be that a nitrate V present or could be that the nitric acid has decomposed into the nitrate.

(JEW No! If you read the bottom, a sample of the mixture - no acid)

Ah yes, well that mistake has been rectified - gives off brown fumes, the brown fumes look to be nitrogen dioxide, er - nitrate V present, so at the moment we've eliminated sulphate IV,

I think it is ZED or Zinc er we've got zinc, could be a nitrate, sulphate IV is out, erm, lets runs back over the tests yellow solid, brown fumes - if carbon dioxide evolved - no carbon dioxide. No carbonate - move back to 2 'b'. A white ppt soluble in hot concentrated hydrochloric acid was obtained, on adding barium chloride solution - white ppt - barium chloride - nitric acid - soluble - I'll move on to 'c'. Sodium hydroxide solution was added to a third portion, a white ppt soluble in excess sodium hydroxide was obtained. White ppt soluble in excess sodium hydroxide was obtained. Well! On the data sheet, white ppt soluble in excess alkali - I think we've just had this, again it was zinc or lead. If it were lead the solid would go red when hot and yellow when cold. It does that. If it was zinc it would go yellow when hot and white when cold, so I think its the lead, its the lead, leave the zinc, stick to the lead. Why we've given away the sulphate IV? Turns limewater milky. Yes - cos it didn't affect the dichromate paper. Erm I think I'll stick to that - I'll leave the sulphate and perhaps I ought to leave it in! Er - sodium hydroxide! White ppt soluble one of the metal ions is lead, looks to be lead, ties in with two of the tests. Yes, er - move to (a) dilute sulphuric acid added to the first portion and then white ppt was obtained insoluble in hot ammonium sulphate solution - dilute sulphuric acid - soluble in hot ammonium sulphate solution! Well this gives calcium and the calcium cannot come from the nitric acid and it doesn't come from the sulphuric acid so - I think another metal ion is calcium and calcium isn't present in the heated strongly test, so at the moment we've got lead and calcium and sulphate is out. That would be the metal ions worked out now. Concentrate on the other ions, the non-metal (a) We've just done (a)!

Sodium hydroxide - no - Solid D was treated with dilute nitric acid and dissolved with effervescence to give a colourless solution and the gas turned limewater milky but did not affect dichromate paper. Er, Solid D dissolved with effervescence - well if it was the solid which effervesced, the solid would have produced the gas, colourless solution was given off. If the solid produced the gas, and it was the gas that turned limewater milky, but did not affect dichromate paper, I think the gas could have been carbon dioxide and a carbonate present, but the dichromate paper being not affected again disproves the sulphur dioxide - gas, so we could have a carbonate - brown fumes on final action of heat gave a nitrate, so there's a nitrate.

At the moment there's lead, and er lead nitrate, carbonate and calcium. So I think lead, calcium, carbonate and nitrate.

Problem Q5

Solid E. Appearance is an off white powder, slightly lumpy I think the slightly lumpy can be discarded, erm - off white powder, well, most of the powdered substances, here powdered zinc, iron, calcium, lead mm tend to be white or off white - chloride sulphate sulphide carb - most of these would give an off white powder. Solubility in water - partially soluble the temperature was dropped and the supernatant liquid was colourless. For a start I don't know what a supernatant liquid is!

(JEW That which lies above)

Thanks! Temperature drops and the liquid lying above was colourless.

Q5

The liquid lying above was colourless, partially soluble, colourless! so! I don't think - just going on information

iron and copper tend to produce coloured solutions, tend to produce coloured solutions, I'll move on I think. E melts, on action of heating, melts, boils, solidifies and gives off a white vapour, which partially condenses. Well, E melts, boils and then solidifies, I think that's fairly obvious. Gives off a white vapour which partially condenses. The white vapour which partially condenses - the white vapour? O.K! The vapour turns moist blue litmus red

(JEW Repeats this twice)

um, acidic vapour - um - could be ammonium - one of these rare occasions again! The solid residue is white - if the solid residue is white when cold, which it is, it looks to be zinc - so, at the moment - phew! we've got zinc and a white vapour - don't know what the - the white vapour - I think is maybe - oh!

Action of heat gives the white vapour - I don't really know what the white vapour. There's no test indicating the white vapour! Um - I think the white vapour bit is irrelevant to the question - I'll maybe come back to that bit later. No action with cold dilute hydrochloric acid - but when it is warmed a pungent smell is evolved. No action with the acid, but warming if necessary. I think the action with acid could be left out - we'll just say action with warmed acid! Um - a pungent smell is evolved, again! this pungent smell mm - bad egg smell, which is hydrogen sulphide - which could be a sulphide present - er - then it turns potassium dichromate paper green! and again - this - well - turning dichromate paper green is a sulphate, sulphate IV and it says "Gas evolved, usually on warming" and it had to be warmed so I think the sulphate IV. So, we've got sulphate IV, maybe ammonium and zinc so far. This gas turns moist blue litmus red

and potassium dichromate paper green, well its an acid gas, so it could easily be the sulphate IV, and the solution remaining is colourless. I think the last part to that question is I suppose the colour of the remaining solution could have something to do with the metal ion present maybe - I'll remember that piece. Action of concentrated sulphuric acid. There is an immediate effervescence and then pungent white fumes turn moist blue litmus red and potassium dichromate paper green, again - seems fairly common, on this dichromate paper test! Er - concentrated sulphuric acid - effervescence immediate, effervescence and a pungent white fumes (mutter) green, and the dichormate paper green, but the sulphate gas could be coming from the sulphuric acid, more than likely. Er they also turn nitrate, silver nitrate, acidified with dilute nitric acid, drop milky - erm - this - the effervescence and the pungent, choking gas, white fumes in air - and turns the silver nitrate drop milky - I think I would dismiss the ammonium, or keep it in the back of my mind, so we've got zinc, chloride and maybe a sulphate IV with the dichromate paper, but the chloride, also I should have thought, would turn the litmus paper from blue to red - move on! On adding sodium hydroxide, to a solution of E in dilute hydrochloric acid, white ppt insoluble in excess sodium, in excess alkali - insoluble. This leads to calcium, there doesn't seem to be a test for calcium with the, so far in the test, with the heating. So I'll keep. So its calcium, zinc, chloride and at the moment sulphate IV erm - if it was a nitrate, there would have been an oily condensate observed when the mixture was warmed and brown fumes are detected whilst adding concentrated sulphuric acid. This wasn't detected so I don't think there's a nitrate present. Sulphate VI on heating the gas evolved - ah

yes - the gas evolved, turns dichromate paper green, we've had a potassium dichromate paper being turned green, but not on heating. It was on the action of dilute hydrochloric acid and that is sulphate IV, er - chloride, I think we've identified sulphate IV - could be, and the carbonate? Heating, there would be a gas evolved which turned limewater milky and this chap seems to have got most tests so if that was there he would have got that, so we can eliminate the carbonate!

Now we move on - ammonium hydroxide solution, "no action".

Erm - ammonium hydroxide solution - pale blue ppt dissolving in excess, to give a deep blue solution - would have been copper II and if it had been copper II the solid would have turned black - it turned white, so copper II can be eliminated also. Potassium hexacyanoferrate II solution, ferrocyanide, no action, I think this relieves, this relieves iron II and iron III. If it was iron, there'd have been a black solid on heating or a red brown solid on heating. Don't think it could be copper, the solid would have gone black on heating, so copper is out, but I thought we'd got zinc, but on this test it should give a white ppt. Soluble in sodium hydroxide solution - mm doesn't say anything about sodium hydroxide being added.

(JEW if there is no white ppt - you can't dissolve it)

Mm, true! Yes - if there's no white ppt you can't dissolve it, that means that - er - there's no white ppt - it can't be soluble in sodium hydroxide. I'm only going for zinc on the part that the solid goes yellow when hot and white when cold - s- that could be dismissed. I'll think about that.

Barium chloride solution - a white ppt formed almost completely soluble in hot concentrated hydrochloric acid. Erm - barium chloride - almost completely soluble in hot concentrated

hydrochloric acid. Well, this leads me to believe it's a sulphate IV, which we proved earlier on when the gas was evolved, turning dichromate paper green, on adding dilute hydrochloric acid. So again we've got sulphate IV certainly, well, almost certainly. Zinc, sort of touch and go and a chloride we found earlier on which was a fairly positive test, however, move on and we also had calcium as well. So we've got calcium, sulphate IV almost certainly and chloride almost certainly.

Silver nitrate a chunky white ppt, chunky white ppt we've got a white ppt but not a chunky white ppt - we'll leave the chunky piece out! It's soluble, fairly obviously, we'll leave the fairly obviously out! When shaken the "residual precipitate" and the sulphuric acid, dilute, was added to a concentrated aqueous solution of E. White ppt soluble in hot ammonium sulphate. Erm - soluble in hot this proves that there is calcium and calcium has been proved, already. So that's all the information! So we've got calcium, certainly, sulphate IV certainly and chloride certainly. We've dismissed all the other non-metal ions. Er, could have been zinc - but that was disproved with the potassium hexacyanoferrate test! Iron - that was disproved in the action of heat, both II and III. Copper II was dismissed in that test. If it was ammonium, in the first test the solid would have sublimed - as this pupil is very observant I'm sure he would have noticed that, unless it did so very quickly. Later on tests for ammonium - sodium hydroxide to a solution of the salt - white ppt insoluble. If it had been ammonium, there would have been a gas evolved which turns red litmus blue and smells of ammonia on warming. I'm sure this undelinquent pupil would not have missed that! So, laughs, so there is calcium, sulphate IV and chloride.

Caistor Tapes 'R'

R2

Well, appearance, solubility in water, action of heat on the solid, action of dilute HCl on solid. Action of concentrated sulphuric acid on solid.

Appearance - pale green crystals - salts of iron and copper tend to be coloured - that could tell me something. Solution and solubility - so it could be iron or copper - soluble giving yellow green solution - that means its soluble - in a coloured solution, so that could be - iron and copper again! Also soluble so it could be nitrate or ammonium - salts. Right! Action of heat, this solid turns white then brown-black, white? then brown-black. Black-brown - mutter - this isn't telling me much! Lets go on - this gives off a pungent white fume, which runs moist - that could be hydrogen chloride - see if there's any hydrogen chloride about? No - could be ammonia - dichromate paper green - here it is, sulphur dioxide evolved. Sulphur dioxide sulphate VI well, that seems pretty reasonable and that'll be the gas given off - so! Sulphate VI. On protracted heating, the type of smell changes - red litmus reverts to blue, yes, that's an alkali - smell changes - probably a different gas coming off, something like that? Not so sure about that - better go on.

Action of dilute hydrochloric acid - on a solution hydrochloric it doesn't say, gases given off so - um - mutter - go on!

Action of concentrated sulphuric acid - there's action apart from a slight dissolution, ah! mutters again, certainly no gas given off so we can rule out chloride, no nitrate all we've got up to now is a sulphate VI. On protracted heating - type of smell changes, and litmus reverts to blue mmm. Solid sublimes - litmus goes blue - don't like that. The following

reagents were added to a solution of B in water: dilute sodium hydroxide solution - potassium ferrocyanide solution, potassium iodide solution, barium chloride solution. See, sodium hydroxide - dirty green ppt, pungent smell on warming red litmus - moist red litmus goes blue - dirty green ppt mmm - got a green jelly like one here, only mention of green in the sodium hydroxide one, so that could be pretty important - what's green - Iron II, Sulphate VI up to now. Pungent smell on warming mm well that would be ammonia - it says here, would turn litmus, turns it blue - ammonia turns it red - no it doesn't! I'm mixed up - ammonia would turn litmus blue and that would be the pungent smell! So ammonia is present and probably, iron II so I've got three ions, up to now. Potassium ferrocyanide mmm medium blue. There's a light blue and a deep blue - so? Well light blue's iron II, which is what I said - so I'm likely to have two cations, so it could be - deep blue - medium blue, I'll keep an open mind about that. Iron II is there, and Iron III could be as well. I'm not sure about that. No action of potassium iodide - mm - potassium iodide - where's that, here we are, so its not lead and its not copper. So I never thought that anyway, so carry on. Barium chloride - white ppt - insoluble in hot concentrated hydrochloric acid - insoluble - white ppt - barium chloride - where abouts was that? Right! White ppt insoluble - sulphate VI which backs up what I said in the earlier tests. So, I'm pretty sure its sulphate VI and ammonia's there - ammonium and iron II and probably iron III as well. Well carry on - silver nitrate solutions - to a solution of B - in dilute nitric acid - no action - no chlorine! I've either got three ions or four. All I really know is the colours of blue is it Iron II or Iron III? mm - yellowy green - pale green crystals Iron? action

of heat - white, then brown-black - I don't get anything out of that, so it could be hiding there - turns white then brown-black, action of heat - says black here - so - look for any inference - well definitely its iron II - whether any iron III is present? Medium blue? don't like that! could have been the solution - dilute? Concentrated sulphuric acid - no action - slight dissolution - nothing at all. Iron and ammonium and sulphate VI probably that's it. Iron II Sulphate VI and Ammonium Sulphate VI.

R3

Solid C, appearance - action of water - action of heat on solid - action of dilute HCl - action of concentrated sulphuric. Well I'll start. Appearance is turquoise powder - coloured - so it could be salts of copper or iron - iron or copper it might be. Action of water. After C had been shaken with water, it settled out to leave a solid residue at the bottom of a blue solution. So - blue solution - its soluble ah - solid residue - it could be two salts - one's soluble and one isn't. Or it could be there's only one salt and its partially soluble. Er - what have I got - say it's two salts - I'm saying its two salts it could be that one could be a nitrate and the other a carbonate salt. Action of heat on solid - solid turns brown black - brown black. Solid turns black - copper II - iron - solid turns red-brown - no - that's no use. No fumes evolved - moist litmus paper was turned red, but there was no visible fumes, moist litmus - red - mutter - gas - sublimes - no fumes - doesn't sublime - brown-black solid, so it could be copper or iron red brown? I suppose it could be zinc iron or copper again. No fumes, so not a carbonate, not a nitrate, not ammonium, just copper or iron which is O.K. cos copper and iron are coloured, which is what I said to start off with. Mmm - it could be copper and iron. Action

of dilute HCl; there was an immediate effervescence, gas turned limewater milky mm dilute HCl, so gas given off - making limewater milky - there's a note here - I reckon! trying to pull a fast one! making me think it's CO₂, when it wasn't! It's going to be er it's going to be sulphur dioxide, cos you haven't added any more potassium dichromate - so! Tricks.

(JEW Check that rubric)

"If you suspect a sulphate IV to be present, before you test for a carbonate, add a little solid dichromate" then add dilute mmm - I don't know - it could be CO₂ - but - I thought - go on a bit - more. Neither litmus paper nor dichromate paper were affected by the gas, nor was there any detectable smell. If it were sulphur dioxide there would be a smell, so I think it is carbon dioxide - probably is a carbonate. Nor dichromate - no sulphur dioxide - it doesn't affect dichromate - I'm still not sure there. Action of concentrated sulphuric acid. There was an immediate effervescence in the cold but no smell detected - there was a gas given off - when heated no further changes occurred - immediate effervescence - effervescence and choking gas, no smell was detected. That's not quite right! mm I don't really know what to do - mutter - when heated no further changes occurred - no brown fumes - not nitrate and you'd definitely smell hydrogen chloride!!

Let's see what I've got - up to now. Could be copper and - or - iron, er - let's see - could be two different salts and this thing about a carbonate (or sulphate?) I've got four possible ions - anions, I'm not very sure about - but I think it could be carbon dioxide - carbonate, limewater goes milky - action of heat on dilute hydrochloric acid - if you suspect - sulphate IV carbonate - dichromate removes sulphur dioxide.

(a) There's no sulphur dioxide to be given off - so you don't need to add the dichromate - or - there was sulphur dioxide and that's what made the limewater go milky - still no better off! phew - copper or iron - carbonate and sulphate - it's soluble if two salts, one's soluble and one isn't. Carbonates are usually insoluble, that could be it, could be what about this sulphur - solubility - blue solution copper sulphate is soluble - it is a blue solution yes! I'm pretty convinced now it could be copper sulphate - oh - which means that it was the sulphur making the limewater go milky!

(JEW would it?)

It says here dichromate removes sulphur dioxide, which could interfere with limewater CO_2 - I suppose there still could be - carbonate - copper sulphate - copper carbonate. I'm not too sure, but I'll say that. I'm not too sure though. (An intrinsic sulphate IV/VI error built in)

R4

Following tests carried out on solid D, a mixture of two salts. Solid D was treated with dilute nitric acid - so - Solid D dissolved - effervescence - colourless solution - so its reacting to give a colourless solution - gas turned limewater milky and did not affect dichromate paper. That's probably CO_2 then - can't see any way in which it can be anything else, did not affect dichromate paper - right! So, is there anything on nitric acid - sulphate? hydrochloric dil - copper - silver nitrate - not involved - so - let's see its reacting with nitric acid - hydrogen nitrate - HNO_3 - aah - effervescence to give colourless solution - given off CO_2 , probably carbonate - solution from (1) was divided into three portions - the following tests were carried out. Dilute sulphuric acid, added to the first portion so you've eliminated your carbonate already. White ppt obtained, insoluble in hot ammonium - sulphate solution

white ppt obtained - so - cations? Probably reacting with your nitrate or your sulphate - insoluble - hot ammonium sulphate - ah - I don't know about that - dilute sulphuric acid - might help me to concentrate - dilute sulphuric acid aah - soluble in hot ammonium sulphate - this is insoluble - so that's got no bearing on that, I don't think so, I suppose it could be calcium which has just been messed about cos its been in nitric acid so up to now I've got carbonate and it could be calcium, but I'm not sure - I'm not sure at all about that! Barium chloride solution's - let's go back again - dilute nitric acid, so its HNO_3 reacting with two salts - and er carbon dioxide being evolved - er I don't know - nitrate? nitrate ion - but with what though - don't know any of the cations yet! I'll have to think about that, anyway I'll go on. Barium chloride to second portion. What happens with barium chloride? Here it is. White ppt soluble in hot concentrated hydrochloric acid - white ppt insoluble in hot concentrated acid, white ppt soluble - so sulphate IV or sulphate VI, I'm not sure about this solubility, like no, I'll say its a sulphite. Carbonate and sulphite, sulphite I'm not sure about, calcium I'm not sure about. Go on again. Sodium hydroxide solution added to a third portion - white ppt soluble in excess sodium hydroxide - white ppt soluble - in excess sodium hydroxide - there's one here that refers its zinc or lead - I've got a calcium here - so it could be zinc calcium or lead zinc or lead or calcium, but its got to be the zinc or lead for sure. Finally a sample of the mixture was heated strongly - solid melted gave off brown fumes and when it had cooled, when cold turned to a yellow solid. Brown fumes - nitro - nitrate present - that could be from the nitric acid. (JEW heat on the solid - it couldn't)

Brown fumes - when cold, turned to a yellow solid - brown fumes and yellow solid - sample of the mixture - ah when it says 'sample of the mixture, does it mean the solution from (1) (JEW No! The solid)

Ah! Ah! right so - heated strongly - so there is a nitrate involved, that's good, well it could be anyway - nitrate, when it had cooled, turned to a yellow solid - nitrate and a yellow solid - aah - not sure about that - let's have a think! Limewater gives carbonate the nitric acid can't stop that one - got to be a nitrate brown fumes. So I think I've got the anions worked out. Cations now - got to be zinc or lead - calcium? I'll come back to that. White ppt was obtained, insoluble in hot ammonia - sulphuric acid so, what have you got - you've got - oh god I've forgotten what the anions were now!! Carbonate - nitrate - carbonate's gone - so you've got a nitrate and two cations, mm lets see now, nitrate, now the - the thing was insoluble and calcium's supposed to be soluble, could it be the nitric acid thing then - oh. Sulphuric acid! I don't like that, at all - soluble - oh dear zinc or lead - addition of sodium hydroxide - white ppt soluble in excess - zinc or lead - aah - calcium? make no progress really. I'll say that its not calcium because of the solubility differences - can't think of - so zinc or lead or zinc and lead. Is there another test for the zinc and lead? Lead salts tend to be insoluble in water - that doesn't help me! Er - solid melted gives off brown fumes, when it had cooled turned to a yellow solid - yellow solid - yellow when hot white when cold - that doesn't make sense - that puts doubt on zinc - but red when hot yellow when cold - when cool it turned to a yellow solid - mm that could be it, it could be lead - rather looks as though its lead and not the zinc - yes! so - carbonate nitrate and

and I'm pretty sure its lead - cations. Let's see if there's any information I haven't really used up now, that I could use. White soluble - no I've got plenty of information from that one! Yellow solid brown fumes O.K. This thing about barium chloride? Don't really know - barium chloride - white ppt, soluble in hot concentrated acid - soluble in hot acids - no - that's to do with the anions and I'm pretty sure about that, it's not sulphate - so sodium hydroxide - let's see - that's no help. Sulphuric acid - white ppt obtained dilute sulph - calcium no! Solid D treated with dilute nitric acid - that's the carbonate worked out. Well I can't think - zinc? lead. So I think it is: lead carbonate and lead nitrate.

Problem R5

Right this data relates to solid E, appearance, solubility in water action of heat, action of dilute hydrochloric acid action of concentrated sulphuric. Let's start! Off white powder - slightly lumpy - so it's colourless that means could be no, copper or iron at all - even if there's two - because even if there was one salt with iron or copper in, there'd be some colour there - off white - so? could be copper or iron, but very doubtful. It's slightly lumpy - that tells me little or nothing - other than the student's a bit enthusiastic! Solubility in water - E was partially soluble - temperature dropped and the supernatant liquid's colourless. Don't understand that, so I'll have to work my way round that! As to "partially soluble" - over enthusiastic! Temperature drops - endothermic reaction - don't like that! got nothing to tell me - supernatant - I'll leave that. Action of heat - it melts - boils - solidifies - melts - solidifies - makes sense - gives off a white vapour, which partially condenses - vapour turns moist blue litmus red ooh - white

vapour - it could be hydrogen chloride! that's a white vapour! - turns litmus, hydrogen chloride - dichromate paper green - we haven't got anything about that - can't think about that one yet! - see! limewater isn't a white vapour - could be over enthusiasm again, I don't know - well - solid residue is white - yellow when hot, white when cold - so it could be zinc - white when cold. Solid goes red-brown - black - can't be that, it was white - solid sublimes - oh - litmus goes blue - definitely not ammonium! - could be zinc - that's about it - I'll go on. Action of dilute HCl - dilute - no action with cold, but when it is warmed a pungent smell is evolved. Can't be hydrogen chloride - this gas turns moist blue litmus red - yes hydrogen chloride - it could be - potassium dichromate green - um - potassium, lets see - no action? "When it is warmed" - sulphur dioxide - the heat test in no. 1 could be the sulphate present - lets - tis hydrochloric acid, it is yes, gas evolved on warming turns potassium dichromate green. So sulphur dioxide evolved - sulphate IV present. Sulphite. It says about pungent smell! ah - bad egg smell - that could be hydrogen sulphide - turns lead acetate paper black - I'm not so sure about that still think that could be hydrogen chloride from the hydrochloric acid - definitely. Sulphite, no doubt about that. Lets go on - no I won't - says remaining solution colourless?. Action of concentrated sulphuric - immediate effervescence - pungent white fumes turn moist blue litmus red - choking gas - fumes - in air - silver nitrate drop milky - pungent white fumes - once again seems to be hydrogen chloride - chlorine present - chloride present. Dichromate green again - only one thing - green don't like that - sulphur dioxide could be - should be HCl - could be a chloride, there again I could be getting mixed up with a - a sulphate. Definitely sulphite and possibly a chloride - I could be wrong about that. They

also turn silver nitrate - acidified - with dilute nitric acid
drop milky silver nitrate - milky - or - milky - milky surely
that's milky - chloride - er chloride in there - silver nitrate
with sulphuric acid er - sulphate - dilute nitric acid - oh -
leave it a bit - come back. Could be a chloride, definitely a
sulphite. Cations? Yes? Following reagents added to a solution
of E in dilute HCl - mutter - sodium hydroxide solution -
ammonium hydroxide solution, potassium ferrocyanide, barium
chloride, silver nitrate solution to a solution of E in dilute
nitric acid and dilute sulphuric acid to a concentrated aqueous
solution of E. Well I'll start. Sodium hydroxide solution -
white ppt insoluble in excess sodium hydroxide - insoluble!
solution - reagents added to solution in dilute HCl - could be
misleading - hydrochloric acid HCl, possibly react with the solid -
no action with cold acid - so just HCl and the salts - no change.
White ppt insoluble in excess sodium hydroxide - so, sodium
hydroxide - added. White ppt insoluble in excess. That leads
to calcium - first anion, cations rather yes HCl wouldn't react
if cold - no calcium in the HCl - calcium and sulphite probably
chloride, ammonium hydroxide solution - no action - where's it
gone so that means that there's no copper, no copper II anyway!
Definitely, almost certainly calcium - no copper! Potassium
ferrocyanide - lets see - no action - so - uh - no iron,
copper, zinc or lead - now - he's likely to mark any action
down - cause by a sort of enthusiastic type, so I can take
it on his word that there is no action, so that rules out four
cations straight away. How many have I got to deal with? Zinc's
out, iron's out, iron II out, calcium stays in and lead goes
out, copper II goes out, ammonium doesn't. Definitely calcium
but could be ammonium there - could be one salt not a nitrate,
Barium chloride solution - right - white ppt almost completely

soluble in hot concentrated hydrochloric. Barium chloride soluble - white ppt soluble - sulphite. I thought it was a sulphite anyway and I'm even more sure now, cos that backs me up - carry on! Silver nitrate solution to a solution of E in dilute nitric acid - chunky white ppt - white ppt - dissolves fairly obviously when shaken - it agrees - residual ppt begins to go grey. Well it backs up my chloride theory so I've got calcium, sulphite and a chloride - so its two salts - residual ppt - don't know. Calcium chloride? was a chloride - HCl before. Oh, there's another one here! Sulphuric acid dilute er -- added to concentrated aqueous white ppt yes! soluble in hot ammonium sulphate - which tells me it was calcium, which I thought before - so - definitely calcium, definitely sulphite and I'm pretty sure its a chloride - well I've got to find another cation - or is it the same cation for both - the only other one it could be is ammonia - pungent smell - let's see - action of dilute HCl no action with cold acid - when warmed pungent smell is observed - nothing about ammonia in the hydrochloric acid inferences.

(JEW Look for ammonium inference - trying to save time)

Sodium hydroxide - no gas evolved - no ammonium present so its calcium sulphite and chloride so its calcium sulphite and calcium chloride.

Caistor Tapes 'S'

S2

First appearance - pale green crystals. On the sheet, it says salts of copper and iron - um tend to produce um coloured solutions or tend to be coloured - so it could be iron or copper - um. The solubility - it gives, says it gives a yellowy green solution - um - from that statement it also infers they produce coloured solutions, so that backs up the statement or inference of copper or iron. For the action of heat - it says the solid turns white, then brown black - um - gives off fumes, which turn litmus red - can't think - dichromate. It says the fumes turn potassium dichromate green, but on the analysis sheet, it says sulphur dioxide evolved - sulphate VI present. Um, can't find anything else to infer. Action of dilute hydrochloric acid - colourless solution is obtained - um - (15) it doesn't have anything which gives a colourless. It won't be carbonate or sulphate IV that confirms it isn't sulphite or sulphide. Reaction with concentrated sulphuric acid. It says there's no action - from slight dissolution. This implies it isn't chloride or nitrate, as these produce positive tests. Um - it says dilute sodium hydroxide to a solution of B - dirty green ppt - pungent smell on warming. From the sheet it says that iron II gives a green jelly like ppt. It also says - I'm sorry - solution not the gas. That would infer iron II present. Potassium ferrocyanide solution gives a medium blue ppt - which er from the sheet - ion II gives a light blue, iron III a dark blue - so it could be iron, but there's nothing definite from that. Um..Potassium iodide solution - it gives no action - so - um - lead II with potassium iodide gives yellow ppt, so that rules out lead II - um - and copper II and ion II. That rules out copper II cos

that gives some sort of a reaction. With barium chloride - there's a white ppt insoluble in water? No in hydrochloric acid - which implies sulphate VI cos that's the reaction it gives from the analysis sheet. Er, silver nitrate - no action - but the test here says dissolve in nitric acid, first - then silver nitrate so you can't conclude anything from that. Shall I turn off now?

(JEW Yes)

Um from all the inferences I think it is iron II sulphate VI.

S3

From the appearance you could say it was a salt of iron or copper because of the turquoise powder um when it's added to water, it left a solid residue at the bottom - of a blue solution - um - which, if it, it doesn't say it dissolves it said, it left a solid residue, so that implies it didn't dissolve in it, but something must have reacted to produce a blue solution to change the colour, I think, so it could be probably insoluble say so it could be a carbonate, or a lead salt other than lead nitrate. Um when its heated it well - brown-black well, from that it could be copper II or iron - it says that moist litmus paper was turned red - no noticeable fumes - um - doesn't give any indication on the analysis sheet; turning litmus red when it's heated, so we can infer from that one that its copper II or iron. From the action of dilute hydrochloric acid, there's an immediate effervescence - and the gas turned limewater milky. From the - gas evolved, which turned limewater milky - infers that carbon dioxide is there, therefore there is a carbonate present. Er, neither litmus paper, nor dichromate paper were affected by the gas, so, that infers that there's um, no sulphite present, cos that gives, affects the dichromate paper. There's no

detectable smell which implies there's no hydrogen sulphide evolved - inferring sulphide present - um - action of concentrated sulphuric acid - um - there's no smell detected but there is effervescence - um - when heated no further changes occurred, from the effervescence, you could infer that hydrogen chloride is evolved, but that would give a smell - so there's no chloride present. From the blue solution - one thinks of copper sulphate - so could copper be there? There was nothing to say sulphate VI was absent, so it could be there. Copper carbonate then possibly sulphate VI.

S4

First test says the solution is treated with nitric acid, one of the tests here is "dissolve the solid in dilute nitric acid". The solid dissolved, so, there wasn't, then tested with silver nitrate, so - it - there is a possibility of chloride. But since the silver nitrate test wasn't done, you can't, that's you can't infer that very strongly. The gas given off turned limewater milky but did not affect dichromate paper. Well, if you add hydrochloric acid to a salt and it gives off, turns limewater milky you can infer a carbonate's present, so we ought to be able to infer that because it was an acid it was tested with. Um - it didn't affect dichromate paper so you can't infer anything positive from that one. Um - it says when dilute sulphuric acid was added to the first portion of um the solution, a white ppt was obtained which is insoluble in hot ammonium sulphate solution, which infers calcium, from the sheet. When barium chloride was added gave a white ppt which was soluble in hot concentrated hydrochloric acid, um - a sulphate VI would give a white ppt - but it's insoluble in - hot - hyd concentrated hydrochloric acid, so it can't be sulphate VI but it could be sulphate IV because that would give

a white ppt which is soluble mmm. Hydrochloric acid. When sodium hydroxide solution was added, it gave a white ppt - soluble in excess sodium - hydroxide um! from the sheet, zinc or lead II would give a white ppt, soluble in excess alkali and so would calcium, mm so from that sodium hydroxide's alkali, you could say that um, it could be a zinc, lead II or calcium. When it was heated it gave off brown fumes - turned to a yellow solid - um - when it cooled - so! um - (15) there's nothing on the sheet which would suggest it's any of the given things, because it says "it turned to a yellow solid" when it was cooled, the only thing which is solid, yellow solid, when it is cooled is lead, but it doesn't say anything about being yellow when its hot, so you can't really apply that test. And then it gave off a brown gas when heated - its brown, brown fumes this suggests nitrogen dioxide, this suggests nitrate present. At this stage carbonate, nitrate, sulphite, calcium, lead probably chloride.

(JEW Lost here so JEW helps)

Carbonate, nitrate established. Sulphite eventually rejected. Lead accepted, zinc rejected. Calcium accepted.

S5

Um - the - from the appearance, it says its an off white powder, slightly lumpy - mutter - appearance - iron and copper give coloured solutions - salts - so could rule out iron and copper. Um says it is partially soluble in water - um - supernatant - mm - (20).

(JEW Watch big long words)

When it was heated melted - solidified, gave off white vapour - vapour turns moist blue litmus red - something acidic there - solid residue is white when cold - could be zinc - from the

action of dilute hydrochloric acid - produces no action from the salt probably is a gas given off which turns blue litmus red - which must be something acidic - mm - turns dichromate paper green, that could be, that could infer that er, sulphate present, cos there is sulphur dioxide, which is acidic - mm solution is colourless so don't think When sulphuric acid is given off, this is added, there is an effervescence and white fumes - fumes turn blue litmus red and potassium dichromate paper green which is - again suggests something acid mm - also white fumes, which says from the - hydrogen chloride - silver nitrate test confirms that so it'll be a chloride present.

Erm. When sodium hydroxide is added gives a white ppt insoluble in excess sodium hydroxide. Calcium also gives a white ppt insoluble in excess alkali. From er, ammonium hydroxide there is no action, so that rules out copper II, which gives a reaction with ammonium hydroxide. Mm. Potassium Hexacyanoferrate gave no action, which rules out iron II, erm iron II copper II Zinc and lead. Barium chloride gives a white ppt - which is almost completely soluble in hot concentrated hydrochloric acid - erm - because its almost completely soluble it gives sulphite rather than sulphate. Erm - when you add silver nitrate solution to a solution of E in dilute nitric acid, get a white ppt - erm - which dissolves and the ppt begins to go grey. The chloride gives the same things. Erm - sulphuric acid - it gave a white ppt which is soluble in hot ammonium sulphate - erm - because they give different reactions - sulphite, chloride and calcium probably.

Caistor Tapes 'T'

T2

Pale green crystals suggest the ferric iron. Solubility suggests it isn't possibly a carbonate, the yellow green suggests iron in some form or another - some form or another. The action of heat suggests there is water present in the salt it turns to the anhydrous form, when the water is driven off. The gas given off suggests its hydrogen chloride with the action of litmus or possibly because of the dichromate it's sulphur dioxide - the hydrochloric acid suggests that the substance dissolves possibly forming a chloride - the sodium hydroxide shows that is possibly iron again, heating shows that sulphur dioxide is being formed. Although the red litmus turning blue suggests that an alkaline gas is being formed and possibly ammonium. The potassium hexacyanoferrate shows iron is again present, either iron II or iron III. The iodide shows it is neither lead or copper. The barium chloride shows that sulphate VI must be present and the silver nitrate shows that there is no chloride present. I'll go back again. Back to no. 3. It suggests that ammonium is given off, after the nitrogen dioxide, sorry sulphur dioxide, this suggests it is a double salt possibly ferric ammonium sulphate - sulphite possibly. Yes going back to the sodium hydroxide it suggests it is definitely ferric iron rather than the ferrous iron, because it is the green jelly like ppt

(JEW Iron II is ferrous - use oxidation numbers please)
therefore we have iron II ammonium and sulphite or sulphate - I'm not sure which yet. Yes the dichromate turning green, suggests it is definitely sulphate VI - so it is iron II ammonium sulphate VI.

T3

Appearance - turquoise powder - suggests it is a transition metal compound of some sort - possibly copper. Erm, the action of water, it suggests there are two compounds present - one soluble and one insoluble - the soluble one possibly copper sulphate and the insoluble one because of the turquoise powder - copper carbonate. The action of heat - suggests that it is again possibly copper - possibly copper oxide being formed - the action of the litmus suggests an acidic gas is given off, possibly carbon dioxide from the carbonate, if it was a carbonate! Yes, the action of dilute hydrochloric acid again confirms the carbonate with carbon dioxide being given up - being given off. There is possibly no action with litmus paper because there is not that much carbon dioxide being given off and litmus is not that sensitive to carbon dioxide anyway. No smell suggests that again it was possibly carbon dioxide - the dichromate could again confirm that. The action of sulphuric acid again shows that carbon dioxide was given off from the carbonate - mmm - when it says heated does it mean gentle heating - no further changes suggest it was again a carbonate. I would therefore suggest it was a mixture of copper sulphate and copper carbonate.

T4

The effervescence suggests that there was possibly a carbonate present, giving off carbon dioxide and the gas given off turning limewater milky - that is the standard test for carbon dioxide which proves the first part - it was possibly a carbonate. No effect on dichromate - erm shows that it was not sulphur dioxide and possibly no sulphate IV. Oh - as the residue from (1) possibly is a nitrate - erm - this is rotten!

(JEW true!)

I can't think of anything on part (a) so I'll move to part (b)

I don't seem to be able to find enough information which would prove anything to me - no chloride present - this suggests that there was no calcium present as the ppt was insoluble - as calcium salts were mainly insoluble - white ppt (barium chloride) suggests there was a sulphate present - a sulphate IV as it was soluble - and the sodium hydroxide suggests it was zinc or lead II present. The heating suggests it gave off nitrogen dioxide therefore a nitrate and cooling to a yellow solid suggests it is zinc possibly rather than lead - yellow when cold - its lead, lead is yellow when cold red when hot. Do you mind if I go back (plays back). Um, lead and nitrate, lead is positive, the nitrate is fairly positive - brown fumes, there is nothing else that would produce brown fumes. Um - the action on dichromate - or no action suggests there was definitely no sulphur dioxide but again, carbon dioxide because of the limewater, which does again suggest a carbonate barium chloride - I can't think of anything else which that would be soluble - I can't think of anything else that barium chloride would react with neither carbonate nor nitrate - I think I will eliminate the sulphate and keep the carbonate.

T5

Appearance - um, lumpy powder, suggests that it is possibly absorbing water in some form - calcium chloride? - partially soluble - possibly again calcium - can't conclude anything from the second part. The melting and boiling suggest it is a compound breaking down in some way - white vapour being given off, the product of this breakdown possibly an acidic, yes, an acidic vapour of some sort. Dichromate paper green suggests sulphate VI present - sulphate IV definitely sulphite - sulphate IV. The action of concentrated sulphuric acid gives

off pungent white fumes as um the last test - possibly um, chlorine, er, but that would give a bleaching effect, so it also shows slight acidic reaction - so possibly chlorine - although white fumes rather than chlorine suggest hydrochloric acid gas, HCl. Yes, turning acidified silver nitrate milky - suggests hydrogen chloride therefore possibly chloride present again. Possibly calcium sulphate IV and chloride. No definite evidence on calcium yet. The sodium hydroxide test again suggests calcium, because of the insoluble ppt, with no real alternatives, ammonium hydroxide suggests there's no copper present. It's fairly definitely calcium now. Barium chloride test suggests sulphate VI, sorry soluble - sulphate IV. So far we've got calcium, sulphate IV, chloride. Silver nitrate in dilute nitric acid suggests a chloride again therefore it is possibly a mixture of calcium chloride and calcium sulphate IV. The last test goes to prove its a calcium - so, its calcium sulphate IV and calcium chloride.

Caistor Tapes 'U'

U2

Pale green crystals - well that could be iron or copper - as they are - solid? It's solutions that are coloured and mutter - ah! Nitrate or ammonium salts - yellowy green solution - that will be iron or copper salts - probably in colour - brown-black - copper II or iron - ah - white fumes - these turn moist blue litmus red and dichromate paper green - mm - ah - dilute hydrochloric acid - colourless solution well - colourless - no gases - no sulphur dioxide, no carbon dioxide - no hydrogen sulphide no sulphates IV nor sulphides nor carbonates there. Concentrated, sulphuric - slight dissolution - no action so it won't be hydrogen chloride or nitrate, not chloride or nitrate dilute sodium hydroxide - green ppt - pungent smell - green ppt - iron II? perhaps - red litmus turns blue - that's alkaline then - mutter - ammonium - in that case. Potassium hexacyanoferrate - medium blue mm - could be iron II or iron III from that. Potassium iodide - that rules out the lead or copper straight away - should be either a white or yellow ppt and its neither. Barium chloride? White ppt insoluble in hot concentrated hydrochloric acid - sulphate VI mm (mutter).

Silver nitrate silver nitrate no chloride there oh! right - Iron II or iron III? Green ppt suggests iron II rather than iron III. Gas turns red litmus blue - when litmus goes blue that's the ammonium. Urm - copper - no - iron sulphate and ammonium.

U3

Coloured powder - again! well, iron or copper would give a coloured solution - water? solid residue at the bottom of a blue solution - iron or copper from that solid residue at the bottom of the tube. Brown-black solid - copper II or iron - moist litmus went red - does show there's no ammonia or

else it might have gone blue or back to red. Give that a miss. Dilute hydrochloric acid - effervescence - gas turned limewater milky which sounds like carbon dioxide evolved - carbonate there - copper or iron carbonate, dichromate not affected - no sulphite at all and no smell ah! - no smell no ammonium if there's no smell. Action of concentrated - effervescence - in cold - no smell - on heating no further changes occurred - so, there'd be no nitrate there - because of no brown fumes - suggests chloride there, copper? copper chloride copper carbonate and iron chloride heated? - mutter - mm. Hang on while I check, doesn't help us - it wasn't that - carbonate - copper? I would probably - I would say its iron chloride and copper carbonate.

U4

Acid - dissolved in nitric acid - effervesced and gave a colourless solution - colourless solution - colourless solution - in that case - did dissolve so there won't be any chloride there with the nitrate - or will it? mm. Gas turns limewater milky but did not affect dichromate paper - immediately rules out sulphite - dichromate milky - limewater milky - carbon dioxide - carbonate there. Three portions - dilute sulphuric - dilute sulphuric - white ppt - insoluble in hot ammonium sulphate - so it's not calcium - carbonate, but no calcium. Barium chloride - gave a white ppt - which would - which was soluble in hot concentrated hydrochloric acid so there is some sulphite. Oh! Dichromate paper wasn't affected - but to say that there shouldn't be except that would tell us there was sulphur dioxide there - which would - perhaps why that would? - there is sulphate there? Sodium hydroxide gave a white ppt soluble - zinc or lead - or both - melted - brown fumes - nitrogen dioxide - lead from yellow and sodium hydroxide

brown fumes - nitrogen dioxide - should be nitrate there, nitrate, or carbonate or sulphite - sodium hydroxide - that's lead - barium chloride, white ppt - it was soluble in hot concentrated acid which gives me sulphite - possibly lead sulphite will affect the limewater in the same way - get rid of the carbonate. Sulphite, nitrate lead - any more? Sodium hydroxide? Calcium not calcium definitely, colourless solution - nitrate sulphite. Three ions lead nitrate and lead sulphite.

U5

Off white powder - slightly lumpy - white powder not likely to be copper - liquid colourless - not iron or copper then as they'd produce a coloured solution - mm - won't be carbonate - could be lead - heated - mm moist blue litmus red - litmus red - white residue, mm, vapourises - pungent no action - pungent smell - hydrogen sulphide - turns dichromate green - smell isn't sulphide - more likely sulphite - colourless solution. Concentrated sulphuric - effervesces - white fumes - blue litmus dichromate green - silver nitrate - oh! chloride present then. Sulphate and chloride. Sodium hydroxide - white ppt insoluble calcium - ammonium hydroxide - not copper. Ferrocyanate - following are out - iron, copper, zinc, lead - calcium in. Calcium sulphite. Barium chloride - white ppt - sulphite again. Silver nitrate - chunky white ppt - soluble in ammonium hydroxide - chloride! Sulphurous acid - white ppt soluble sulphite, chloride - sulphite chloride and calcium.

Caistor Tapes 'V'

V2

As the appearance suggests, or a coloured anion, possibly iron or copper - the - solubility suggests that it might be nitrate or ammonium salt, but it is not - isn't sufficient evidence to suggest or ... (50 sec. - very long silence) leave section three (25) Part 4 - no help whatsoever (20) at all and Part 5 as there is no action apart from a slight dissolution you can infer from the evidence neither a chloride nor a nitrate is present (30). In part four - no six the pungent smell and the fact the red litmus turns blue could indicate ammonia to be present. The hexacyanoferrate test with the blue ppt suggests iron III to be present in the salt. The fact that potassium iodide has no effect suggests that no lead and no copper II to be present. White ppt insoluble in hot concentrated hydrochloric acid - insoluble suggests sulphate IV to be present. Part 10 has no more bearing. From the evidence suggested by the sheet, I have found the possibility of three - lead, sulphate IV and ammonium. The ammonium was suggested due to part 6 of the pungent smell in the turning red litmus to blue. The sulphate IV was suggested by the barium chloride ppt insoluble in hot hydrochloric acid and also in part 3, the dichromate turned green suggests sulphate to be present. Lead has been derived from the fact that it goes red when hot yellow when cold sorry iron from the ferrocyanide test and the coloured salts coloured solutions. Iron sulphate IV recorded as verdict.

V3

The appearance suggests a coloured compound - turquoise, which suggests - a salt of iron or copper. The salt is insoluble in water - at this - it would suggest a carbonate or either

iron or copper or a lead salt to be present. There's no visible fumes - this suggests a nitrate isn't present as nitrogen dioxide would be evolved and these are brown fumes. The fact that the solid turned brown black could infer copper or iron present - they're much the same colour. The effervescence and the fact that the gas turned limewater milky suggests a carbonate to be present - as there was no smell, it suggests sulphur dioxide wasn't evolved, therefore since there was no detectable smell, hydrogen sulphide was not evolved, therefore sulphide isn't present. The fact that dichromate wasn't altered in any way suggests that sulphate VI sorry sulphate IV was absent. When sulphuric acid was present there was effervescence, but it suggests hydrogen chloride wasn't the gas evolved as the smell was detected. If hydrogen chloride was detected there's a stiffling smell - you'd choke! From the evidence suggested there is either iron or copper. The second part to be a carbonate or sulphate. From part 2 I think this is copper carbonate.

V4

Second part of the observation and turned limewater milky, suggests a carbonate could be present - in the first part if there was a chloride present there'd have been a white ppt going grey - no - probably carbonate. The fact that a white ppt would form might suggest calcium, but due to being insoluble in hot ammonium sulphate - it would disregard that - unless the observation was wrong? - no - all observations are correct. In part (b) a white ppt soluble in hot concentrated hydrochloric acid would suggest sulphate IV to be present - sulphate VI not. The white ppt forming in part (c) soluble in sodium hydroxide, would suggest zinc or lead II to be present. The heating of the metal and giving off of brown fumes would suggest nitrate to be

therefore copper again not to be present or else a brown ppt, also iron II and II not to be present as they would have formed blue ppts. A white ppt formed when barium chloride being almost soluble in the acid would suggest sulphate IV to be present. The fact that, in test 10, it dissolves in excess, the ppt dissolves when shaken with ammonium hydroxide - white - should have been blue - copper not present - should have gone to blue not colourless - so I'm - so in dilute, the formation of white ppt and it turning grey on leaving water suggests a chloride to be present. Part 10 - I mean 11 - no immediate answer obvious - sulphate chloride copper? no calcium - a white ppt could indicate presence of calcium and it is soluble in ammonium sulphate. (long think in silence). Trap suspected - too obvious - chloride present no. 5 absolutely conclusive so is sulphate IV. Chloride would turn litmus red. No. 4 - would prove sulphate IV is present - turns dichromate green and needs to be heated, Therefore I'll stick, sulphite, chloride calcium.

