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FOREWORD

This booklet contains reports written by Examiners on the work of candidates in certain papers. **Its contents are primarily for the information of the subject teachers concerned.**

CHEMISTRY

GCE Advanced Level and GCE Advanced Subsidiary Level

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| <p>Paper 9701/01 Multiple Choice</p> |
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| <i>Question Number</i> | <i>Key</i> | <i>Question Number</i> | <i>Key</i> |
|------------------------|------------|------------------------|------------|
| 1 | C | 21 | C |
| 2 | B | 22 | B |
| 3 | A | 23 | C |
| 4 | B | 24 | A |
| 5 | C | 25 | C |
| 6 | D | 26 | B |
| 7 | B | 27 | B |
| 8 | C | 28 | B |
| 9 | D | 29 | D |
| 10 | A | 30 | A |
| 11 | C | 31 | B |
| 12 | C | 32 | C |
| 13 | B | 33 | B |
| 14 | D | 34 | D |
| 15 | B | 35 | A |
| 16 | A | 36 | C |
| 17 | A | 37 | C |
| 18 | D | 38 | B |
| 19 | B | 39 | B |
| 20 | C | 40 | D |

General comments

For this Paper, the mean score was 22.3 (fifty-five percent), slightly below the targeted value of sixty percent, and the standard deviation of the scores was 6.21 (sixteen percent), indicating that the Paper performed satisfactorily. There was a wide distribution of mark totals, but the responses of candidates to some questions revealed some rather surprising areas of misunderstanding.

The first thirty questions were simple completion items: **Questions 31 - 40** were three-statement multiple completion items.

Comments on specific questions

Four questions had a high facility. These covered the definition of an isotope (**Question 4**), the calculation of a standard enthalpy change of formation (**Question 11**), the way a long alkane chain breaks down during cracking (**Question 22**), and that aspect of chlorofluorocarbons (CFCs) that leads to the destruction of the ozone layer. These are clearly areas of the Syllabus that are widely understood.

Two questions failed to distinguish between the more able and less able candidates. **Question 20** asked how many alcohols (including both structural isomers and stereoisomers) can have the molecular formula $C_4H_{10}O$, and the wide distribution of answers clearly indicates that candidates were either guessing or found this question too difficult at this stage of their experience of the subject: this is to be regretted as the essential chemistry of this question is basic to the Syllabus and is usually taught at an early stage in covering the organic section. In **Question 32** the reaction between graphite and steam was given:



A proportion of the more able candidates, in explaining why the forward reaction is more likely to occur at high temperatures, appear to believe that hydrogen and carbon monoxide do not react at high temperatures - and this in an equation clearly written as an equilibrium.

Four other questions indicated that there were misconceptions among some of the more able candidates. In **Question 8** a very small proportion of candidates (four percent) thought that paper 'melts over a range of temperature'. **Question 29** concerned the mechanism of the (nucleophilic) addition of hydrogen cyanide to a ketone (pentan-3-one), a common topic in these Papers, and yet the range of responses was very surprising. The statistics tell their own story: eighteen percent thought the product has a chiral centre; twenty-one percent that it is formed by electrophilic addition; thirty percent that it is formed through a C-OH intermediate, and only thirty percent correctly appreciated that a cyanide ion is needed as a catalyst. Past Papers have consistently highlighted this last aspect. In **Question 38** the displayed formulae of ribose, menthol and maleic acid were given, candidates being asked which of these contain at least one chiral centre: despite menthol having three such centres, the combination of answers indicates that thirty-seven percent of candidates did not think it would have optical isomers. The most surprising response came in **Question 40**, in which candidates were asked to identify those products of the hydrolysis of methyl butanoate, $CH_3CH_2CH_2CO_2CH_3$, with $NaOH(aq)$ that would be in a subsequent distillate. Whereas eighty percent correctly identified CH_3OH , 70% thought that the salt, $CH_3CH_2CH_2CO_2Na$, would have distilled over.

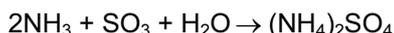
All other questions performed within the design limits, but three need further comment.

Question 16 was concerned with the dissolution of $AgCl$ on photographic film by sodium thiosulphate:



A high proportion of candidates (fifty-four percent) thought that the Ag in $AgCl$ is either oxidised or reduced in this process.

In a not dissimilar question, **Question 31**, in the reaction:



Fifty percent of candidates thought a redox process is involved, and twenty-four percent did not think that an ionic bond is formed.

In **Question 35** the use of lime in agriculture was examined: forty-eight percent of candidates did not appreciate that atmospheric CO_2 would react with $Ca(OH)_2$ spread on the land.

Paper 9701/02

Theory 1

General comments

The standard of many of the candidates who took this Paper was commendably high and there was a pleasing number of candidates who scored very high marks. Unlike previous years however, there was a significant number of candidates who scored very low marks.

There was good evidence that many candidates had learnt much of the factual material required by the Syllabus. However, when candidates were expected to apply their knowledge and understanding to unusual contexts, many struggled to explain clearly the chemistry involved. There were also many candidates who experienced difficulties with the calculations.

The majority of candidates followed specific instructions - such as that in **Question 1 (a)** to sketch part of the crystal structure of sodium chloride or that in **Question 3 (a)(ii)** to write an equation, with state symbols - very carefully. There was, however, a significant number who did not do so and were penalised as a result.

There was also a significant number of candidates whose handwriting caused Examiners considerable problems. In extreme cases, illegible answers cannot be given any credit.

Comments on specific questions

Question 1

This question tested candidates' knowledge of the structure of sodium chloride and of the important industrial production of chlorine from brine. Many candidates scored high marks on this question.

- (a) Most candidates knew that sodium chloride has a giant ionic structure and were able to draw a part of the crystal structure showing Na^+ and Cl^- ions. Fewer candidates represented the three-dimensional nature of the crystal lattice in their diagrams and only a very small number indicated clearly that each cation is surrounded by six anions and each anion by six cations.

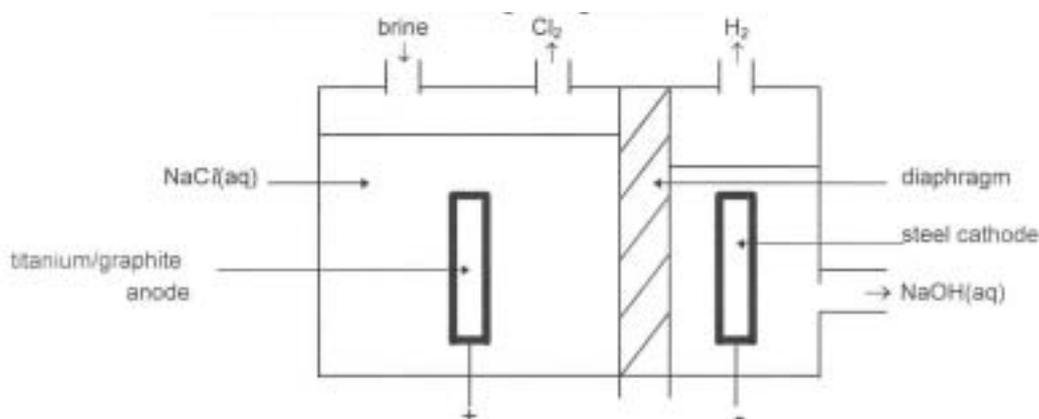
A surprisingly large number of candidates contradicted themselves by making statements such as 'The bonding in sodium chloride is ionic, with strong forces between the molecules.' Such contradictory answers cannot be given any credit.

- (b) Many candidates were able to explain the lack of conductivity in the solid lattice by stating that the ions are fixed in position and cannot move, whereas in molten sodium chloride the ions are free to move and act as charge carriers. There were many candidates who mistakenly tried to explain the conductivity, or lack of it, in terms of movement of electrons. There was also a significant number who wrongly believed that when sodium chloride is melted the ions are produced by the process of melting.

- (c)(i) The question asked candidates to describe in outline the diaphragm cell for the electrolysis of brine - as required by the Syllabus section 6(b)(ii). There was, however, a large number of candidates who answered the question in terms of the mercury cathode cell. It is important that candidates pay careful attention to what is required by the Syllabus in order that they are not disadvantaged.

While there were many good diagrams, there were also many candidates who drew incomplete diagrams. In particular, electrodes were often omitted.

What Examiners were looking for is given below:



- (ii) Most candidates were able to give the required electrode equations correctly. There were some, however, who omitted the state symbols which were specifically asked for in the question, and a small number who gave two correct half-equations but assigned each of them to the wrong electrode.
- (iii) Many candidates correctly identified the two by-products and gave a commercial use for each one. A surprising number of candidates thought that chlorine was a by-product, despite it being identified as the main product in the question.

- (iv) Relatively few candidates appreciated that there must be a reaction between chlorine and the aqueous sodium hydroxide produced by the electrolysis and even fewer were able to give an equation for this.

Question 2

This question tested candidates' knowledge and understanding of the effects of car exhaust fumes on the atmosphere. Few candidates were able to score more than half marks for this question.

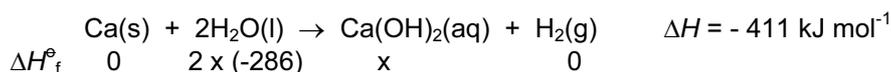
- (a) The vast majority of candidates answered this question correctly.
- (b)(i) Only a small number of candidates identified the major gas in a car engine's exhaust as nitrogen.
- (ii) Most candidates appreciated that water vapour is always produced when hydrocarbon fuels are burned and is therefore always present in the exhaust gases from a car's engine.
- (c)(i) The majority of candidates knew at least one poisonous gas from the list given although the effect of the gas on humans was often phrased in a very general manner. Examiners were looking for specific statements such as 'carbon monoxide reacts with haemoglobin in the blood and prevents the transport of oxygen.'
- (ii) Many candidates were able to provide equations which showed how harmful gases react inside the catalytic converter. However, a significant number of equations were unbalanced and candidates were penalised.
- (iii) Only a small number of candidates were able to explain that some gases, such as CO₂ and SO₂, pass unchanged through the catalytic converter but then contribute to 'global warming' or the formation of 'acid rain' respectively. Very few candidates understood that when the car engine is first started the catalytic converter, which is cold, is very ineffective.

Question 3

This question tested candidates' ability to use the laws of chemical thermodynamics in calculations. Many candidates found at least one part of the calculation difficult, often because they had not written down the balanced equation from which to work.

- (a)(i) The majority of candidates gave correct definitions of ΔH_f^\ominus . There were some candidates who omitted to begin their definition with 'It is the heat enthalpy change when ...' or a similar such phrase. Without this introduction, any definition is meaningless and is not given any credit.
- While many candidates knew the meaning of the term *standard*, there was a significant number who wrongly stated the temperature as 273 K rather than 298 K.
- (ii) Many candidates answered this question correctly. Common errors in the equations given were to produce H₂O(g) rather than H₂O(l) or to produce two moles of water rather than one.
- (iii) Many candidates failed to realise that the reaction is the same as the correct answer to part (a)(ii).
- (b)(i) The majority of candidates answered this question correctly.
- (ii) Although many candidates correctly applied the expression 'heat released = $mc\Delta T$ ' there were many who made fundamental errors. These included using the mass of calcium rather than water and converting the temperature change of 12.2 °C into Kelvins. A *change in temperature* of 12.2 °C is of the same magnitude as a *change in temperature* of 12.2 K.
- (iii) At this stage of the question, many candidates began to struggle. The answer is obtained by taking the answer to part (b)(ii) - which is the heat released by 1.00 g of calcium - and multiplying it by 40.1. The answer must be given with a negative sign because the reaction is endothermic. Candidates who failed to do this were penalised.
- (c)(i) Most candidates were able to quote Hess' law correctly.

- (ii) Many candidates struggled with this question. In order to have any chance of answering it correctly, a balanced equation must first be written.



If the ΔH_f° values are then added, as above, the calculation becomes

$$\Delta H_{\text{reacn}} = x - 2(-286) = -411,$$

whence $x = -983 \text{ kJ mol}^{-1}$.

As before, the sign is necessary.

Common mistakes were to omit to double the value -286 or to have an incorrect thermochemical cycle.

- (d) Many candidates struggled with this question. Again, a balanced equation is necessary in order to show that one mole of calcium yields 24 dm³ of hydrogen at room temperature and pressure. It should then be a routine operation to show that 1.00 g of calcium will produce 598.5 cm³ of hydrogen at room temperature and pressure.

Answers: using Ca = 40.1 (b)(ii) heat released = 10.25 kJ, (iii) $\Delta H_{\text{reaction}}^\circ = -411 \text{ kJ mol}^{-1}$; (c)(ii) ΔH_f° of Ca(OH)₂ = -983 kJ mol⁻¹; (d) volume of H₂ = 598.5 cm³ at room temperature and pressure.

Question 4

This question tested candidates' knowledge of organic chemistry from the early part of the course. A large number of candidates showed very good knowledge of much of the chemistry required.

- (a)(i) Most candidates knew that this was a dehydration or elimination reaction.
- (ii) The majority of candidates were able to produce a correct equation for this reaction.
- (b)(i) Most candidates knew the colour changes involved in this reaction. Examiners did not accept 'clear' or 'white' as alternatives to 'colourless.'

Most candidates were able to write a correct equation for this reaction. The most common mistake was to give an unsaturated bromine compound as the product or to add HBr rather than Br₂.

- (ii) Most candidates knew the colour changes involved in this reaction. Examiners did not accept pale pink as the final colour because dilute solutions containing the Mn²⁺ ion appear to be colourless. A surprising number of candidates gave the colour change for acidified dichromate (VI) ions rather than acidified manganate (VII) ions.

Many candidates struggled with the equation. As stated in the Syllabus, section 10.1(b)(vi), the symbol [O] is acceptable for organic oxidation reactions. The equation can thus be written as follows.



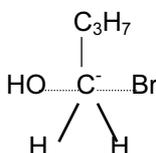
- (c) Both parts of this question were very well answered. Examiners were very pleased that the majority of candidates gave *two* repeat units and showed bonds to the rest of the polymer molecule.
- (d)(i) Most candidates were able to work out the molecular formula of cyclohexene. A significant number failed to present their answer as a *molecular formula*, for example writing instead CHCH₂CH₂CH₂CH₂CH and were penalised.
- (ii) The majority of candidates were able to calculate the required percentage correctly.

Answers: (d)(i) C₆H₁₀, (ii) 87.8% of carbon by mass.

Question 5

This question tested candidates' knowledge of an important reaction mechanism and their ability to deduce what is produced or what reagents are required in a sequence of reactions. While many candidates knew much of the factual material involved, the reaction mechanism was poorly described by a significant number.

- (a)(i) Most candidates were able to write a balanced equation for the reaction. The most common error was to omit the inorganic product, NaBr. Examiners readily accepted equations involving either NaOH or OH⁻.
- (ii) The type of reaction - nucleophilic substitution - was known by most candidates. The most common error was to forget the word 'nucleophilic'.
- (iii) Many candidates struggled with this question although the mechanism is specifically referred to in Syllabus section 10.3(b). Examiners expected candidates to show the presence of the C^{δ+}—Br^{δ-} dipole and explain that the OH⁻ ion will attack the C^{δ+} atom. A significant number of candidates who successfully explained this failed to show that it is a lone pair of electrons on the OH⁻ ion that attacks the C^{δ+} atom. Few candidates were able to draw a structure showing the formation of an intermediate such as the following.



Only a small number of candidates then explained that the Br⁻ is then lost from the intermediate.

- (b)(i) Most candidates knew the type of reaction involved.
- (iii) The majority of candidates gave at least one correct structure. Common errors were to give alkenes with the wrong number of carbon atoms or, in structure II, to give but-2-ene rather than 2-methylpropene.
- (iii) Many candidates gave correct organic oxidation products. The most common error was to give butanoic acid rather than propanoic acid as the oxidation product from compound I. Answers for the oxidation product from compound II were very mixed with a smaller number of candidates correctly giving propanone as their answer.
- (c) Many candidates found this question difficult. The reaction sequence given in the question shows an increase in the number of carbon atoms, suggesting that KCN must be used in one step. Thus step I involves heating the bromide under reflux with alcoholic KCN. The resulting nitrile is then hydrolysed by heating under reflux with a mineral acid to give the required organic acid. Candidates who used aqueous sodium hydroxide for this second stage without further acidification were penalised because their product would have been the sodium salt of the required acid.

Paper 9701/03

Practical Test

General comments

The Examiners thank Supervisors who provided results for the experiments as these were used in assessing accuracy marks for the practical work of each candidate.

The Examiners also thank Centres who provided full information with regard to candidates in each session and laboratory. There are boxes on the front of the Question Paper for this information but these were not always completed. Centres were asked to provide separate Supervisor data for the experiments carried out in each session and each laboratory. Without this information Examiners may not notice any variation in solution concentration or other variable between laboratories, and candidates may be disadvantaged.

Centres are reminded that they should provide a seating plan for each laboratory.

The Paper was tackled successfully by most candidates and there was no evidence of lack of time to complete the Paper.

Where local difficulties arise with regard to the supply of a specified chemical it is essential that appropriate alternatives are discussed with the Product Manager (Subject Officer) at CIE.

Comments on specific questions

Question 1

The practical exercise involved weighing, heating and reweighing - taking care to lose no weighed solid during this procedure. The Examiners are pleased to report that nearly all candidates recorded their weighings to at least 2 decimal places. The apparatus requirement in the Syllabus is for balances able to read to 0.01 g or better. The Examiners were checking that all weighings (first four lines of Table 1.1) were recorded to 2 or more decimal places. It was unusual not to award the mark for this precision of working.

More than 50% of candidates calculated the mass of water driven off for the final line of Table 1.1, rather than the mass of solid remaining. The Examiners have no explanation for this.

Accuracy marks

The Examiners calculated the ratio $\frac{\text{mass of water driven off}}{\text{mass of anhydrous sodium carbonate}}$ for each candidate and compared the value obtained (correct to 2 decimal places) with that obtained from the Supervisor's results. Sodium carbonate-10-water should give a value of 1.70 but as samples age and effloresce the value goes down.

Accuracy marks were awarded on a widening sliding scale as the difference between candidate and Supervisor's ratio increased. Different, proportional, scales were applied where the Supervisor's results in a Centre were approximately 1.60; 1.30; 1.00; 0.60; 0.30. e.g.

| Mark | Difference to Supervisor | |
|------|--------------------------|------------------------|
| | Supervisor ≥ 1.60 | Supervisor approx 0.60 |
| 5 | 0.00 to 0.10 | 0.00 to 0.04 |
| 4 | 0.10+ to 0.20 | 0.04+ to 0.08 |
| 3 | 0.20+ to 0.30 | 0.08+ to 0.12 |
| 2 | 0.30+ to 0.40 | 0.12+ to 0.16 |
| 1 | 0.40+ to 0.60 | 0.16+ to 0.24 |
| 0 | Greater than 0.60 | Greater than 0.24 |

- (a) A substantial majority of candidates have no understanding of the concept of "heating to constant mass". Reference to continued heating until there was no change in mass was required to gain the mark.

The Examiners saw many answers that described no more crackling on heating; no condensation on the tube; no "steam" being given off.

- (b) Nearly all candidates correctly calculated the mass of crystals at the start of the experiment. The subtraction had to be correct to gain the mark in (b).
- (c) An incorrect mass of anhydrous sodium carbonate in the last line of Table 1.1 was not penalised but if it was subtracted from the answer to (b) at this stage the mark for (c) was not awarded. The mass of water driven from the crystals had to be correct for the experimental data to gain the mark in (c).
- (d) The percentage of water in the sample of FA 1 was marked consequentially from the candidate's answer to (b) and (c). This mark was awarded to nearly all candidates.

Question 2

The percentage of water in sodium carbonate crystals was obtained by an alternative titration method.

The masses in Table 2.1 were again recorded to 2 decimal places by a large majority of candidates and providing the subtraction was correct, the mark for Table 2.1 was awarded.

The Examiners were pleased to note that nearly all candidates record their accurate burette readings to 2 decimal places.

For a grade B burette, $1 \text{ cm}^3 =$ approximately 20 drops. The notes on practical techniques in the Syllabus explains that burette readings should be recorded to the nearest 0.05 cm^3 (i.e. 1 drop) and two titres within 0.10 cm^3 is considered sufficient for the examination.

One mark was awarded in Table 2.1 for final burette readings recorded to 2 decimal places and the burette volume in the correct places in the table (i.e. not inverted). Any titre recorded as Rough did not need to be recorded to 2 decimal places. This mark was not awarded where “impossible” readings such as 23.47 cm^3 were recorded as final or initial burette readings.

The second mark in Table 2.1 was given if subtraction was correct for each titre, there were two titres within 0.10 cm^3 and an appropriate average was calculated from indicated titres. (A spread penalty was applied to the accuracy marks where titres differing by more than 0.20 cm^3 were used when deriving the average).

Accuracy marks

The Examiners corrected any errors in subtraction in Tables 2.1 and 2.2 and calculated (to 2 decimal places) for Supervisor and candidates:

$$\frac{3.50}{\text{mass of crystals dissolved}} \times \text{titre}$$

Accuracy marks were awarded on a widening sliding scale for the difference between candidate and Supervisor. Those within 0.20 cm^3 were awarded the full 6 marks, those with a difference between 0.25 cm^3 and 0.30 cm^3 , 4 marks; and those with a difference between 0.50 cm^3 and 1.00 cm^3 , 2 marks etc.

Where no Supervisor's results were provided in question 2, the “standard” titre for 3.50 g of the original solid was calculated from the Supervisor's results to **Question 1**.

- (a) Nearly all candidates were able to correctly calculate the moles of hydrochloric acid run from the burette.
- (b) Most candidates correctly halved the answer to (a) to obtain the moles of sodium carbonate reacting but some missed the dilution factor for moles of sodium carbonate in 250 cm^3 of **FA 3**.
- (c) The mass of sodium carbonate was correctly calculated by the majority of candidates. This section was marked consequentially from the answer in (b). Candidates who introduced the x10 dilution factor in (c) were not penalised but there was no retrospective mark awarded in (b).
- (d) The majority of candidates correctly subtracted their answer to (c) from the mass of crystals weighed out. A few candidates assumed $10\text{H}_2\text{O}$ and calculated a theoretical mass of water associated with the mass of anhydrous sodium carbonate in (c).
- (e) The candidates who gained the mark in (d) went on to divide their answer to (d) by the mass of crystals to find the percentage. Those who had assumed $10\text{H}_2\text{O}$ continued with a theoretical mass of crystals and did not use the mass weighed for the experiment.

Where candidates made an error in either experiment and ended with very different calculated percentages for the water contained in the crystals there was little evidence of checking calculations to find the error – the different values were accepted.

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| Paper 9701/04 |
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| Paper 4 |
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General comments

The Paper performed well, and there was a good spread of marks suggesting that the Paper had differentiated well between the candidates. There was little evidence that candidates did not have enough time to complete the Paper, although, as was found in the May examination, there were a few candidates who did not seem to turn over the last page to answer the last question, despite the “**Turn over**” statement at the bottom of page 11.

Comments on specific questions

Question 1

- (a) This was quite well answered but weaker candidates did not mention the key word *concentration* in their answer and just referred to reactants. Some referred to *power being raised to concentration* rather than vice versa.
- (b) This was also fairly well answered, although some candidates were not good at interpreting data. The popular incorrect response involved (I₂) as well as (propanone) and (H⁺) in the rate equation. Sometimes candidates omitted “*k*” from the equation or attempted to give an equilibrium constant expression.
- (c) The most common errors involved thinking that graph **B** (rather than **A**) described how the propanone concentration varied, and graph **C** (rather than **B**) the iodine concentration.
- (d) The graph was usually plotted correctly although many candidates either did not draw the line or else did not realise that the line should have begun at the origin.
- (e) Most candidates gained credit for suggesting that the overall rate depended on the slowest step which was identified as the rate determining step. However, only the more able candidates then linked this to the correct mechanism. Mechanism **B** is the only one in which *only* propanone and H⁺ are involved in or before the rate limiting step.
- (f)(i) The majority of candidates did not gain credit because they simply referred to a titration or to the use of thiosulphate without linking the two. Better candidates knew about colorimetry.
- (ii)(iii) With the help of consequential marking, the majority of candidates were able to gain credit for calculating a value for *k* and for giving the units. Weak candidates had problems with the negative indices. Several candidates, although using the right expression, did not extract the correct concentrations of [propanone] and [H⁺] from the data given in the question.

Answer: (f)(ii) $3.3 \times 10^{-5} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$.

Question 2

- (a)(i) Most candidates were able to write an expression for K_a , although some wrote $K_a = [\text{H}^+][\text{OH}^-]/[\text{HA}]$.
- (ii) Able candidates correctly calculated the hydrogen ion concentration, while weaker candidates seemed unable to deal with the square root. Candidates should be reminded that numerical answers to this (and other) questions should be given to no more than three significant figures.
- (iii) Again, this was quite well answered although weaker candidates had problems coping with the mathematics. In this and in part (iv), marks were awarded for the correct use of an incorrect [H⁺] calculated in part (ii).
- (iv) The majority of candidates could correctly calculate a pH value consistent with the hydrogen ion concentration given in part (ii).

- (b) Most candidates had no problem in calculating the pH of the hydrochloric acid, although some quoted a negative pH value.
- (c)(i) Only the most able candidates were able to write a balanced equation for the reaction between magnesium and methanoic acid. Many thought that magnesium methanoate was "HCO₂Mg" (thinking that the magnesium ion was Mg⁺) and others gave MgO or MgCO₃ as the magnesium compound formed. Some equations did not include hydrogen as a product!
- (ii) This was quite well answered. Most candidates calculated the number of moles of acid used, and then used their equation to calculate the volume of hydrogen produced. Answers assuming that the molar volume was 22.4 dm³ instead of 24 dm³ were accepted. Some candidates who had been unable to write an equation in part (i), correctly wrote an equation using hydrochloric acid, and then gained credit based on that.
- (iii) Although most candidates recognised that methanoic acid was a weak acid, many did not explain this in terms of partial dissociation/ionisation. Since the reaction is one between H⁺ and Mg, the smaller the [H⁺] is, the slower will be the rate.
- (iv) Only the most able candidates demonstrated their understanding of dynamic equilibrium by giving an answer in terms of the shift of the ionisation equilibrium to the right as H⁺ ions are used up, resulting in the eventual reaction of all HCO₂H molecules.

Answers: (a)(ii) $2.97 \times 10^{-3} \text{ mol dm}^{-3}$, (iii) 6.0%, (iv) pH = 2.5; (b) pH = 1.3; (c)(ii) volume of H₂ = 12 cm³.

Question 3

- (a) Strong candidates scored well on both parts to this question. Common errors involved candidates quoting incorrect data (e.g. using the Fe/Fe²⁺ half equation instead of Fe²⁺/Fe³⁺ in (i)) or reversing the half equation (e.g. having Fe³⁺ reacting to form Fe²⁺). In part (ii) many candidates did not appreciate that the H⁺ and H₂O needed to be reorganised and the equation written in its simplest form. A few used the wrong half equations (e.g. SO₄²⁻/SO₂ or S₂O₈²⁻/SO₄²⁻ in (i)). The reaction involving the reduction to MnO₂, MnO₄⁻ + 4H⁺ + 3Fe²⁺ → MnO₂ + 3Fe³⁺ + 2 H₂O, was accepted.
- (b)(i) The majority of candidates knew that potassium manganate(VII) solution is purple, but a few confused this with the orange colour of potassium dichromate(VI).
- (ii) This part was very poorly answered: the end point of the titration is the appearance of the first faint permanent pink colour in the (colourless) solution. The majority of candidates had not appreciated that the potassium manganate(VII) was being added from the burette and thought the change was from purple to colourless, or from pink to colourless.
- (iii) With the aid of consequential marking, most candidates were able to score 2 or 3 marks for the calculation. A significant number calculated the mass of iron in the tablet rather than the mass of iron(II) sulphate.
- (c)(i) Many candidates gained no credit because their answer lacked depth, simply stating that the blood carries oxygen and that haemoglobin in the blood contains iron. Good candidates suggested that oxygen is transported around the body, to tissues/cells etc., and that molecular oxygen is attached to the iron (or Fe²⁺) in haemoglobin by a dative bond. A popular incorrect response was the suggestion that iron(II) acted as a catalyst which was oxidised by oxygen to iron(III), but was reformed when the oxygen was released.
- (ii) Good candidates described carbon monoxide as forming *stronger* bonds (or being a *stronger ligand*) with haemoglobin than oxygen. Incorrect ideas sometimes involved carbon monoxide dissolving in the blood to form carbonic acid, which gave blood a poisonous pH.

Answer: (b)(iii) 0.106 g.

Question 4

- (a) Good candidates clearly identified the phenol and ester functional groups in the compound. Weaker candidates thought the substance contained alcohol (or hydroxy) and carbonyl groups.

- (b)(i) This was generally well answered, with candidates recognising that the phenolic hydrogen was replaced.
- (ii) The formation of ethanol was well known (although not universally stated by candidates), but candidates were less successful in writing the formula of the other product. Many thought that the phenolic hydrogen remained intact, rather than ionising, to form the dianion. A few candidates lost a mark for showing covalent bonds between the oxygen and sodium atoms.
- (iii) Many candidates realised that there was multiple substitution in the ring. Responses that received no credit included structures involving side chain substitution or monobromination of the ring.
- (c)(i) Sometimes candidates did not make clear whether the order stated meant that the acid strength was increasing or decreasing. Stating the list as G, E, F was not read as $G > E > F$: it could have meant $G < E < F$. Credit was given, however, if the answer to part (ii) clearly described the relative acidities correctly. Some candidates confused *order of acidity* with *order of reaction*! One common error was to state that substance E was the least acidic (thinking that phenols were less acidic than alcohols). Others, however, stated that E was the most acidic because it could “use up” the NaOH when hydrolysed.
- (ii) Able candidates expressed themselves well and sequenced their ideas logically. However, very many candidates had little knowledge of the chemistry of these tests, and several thought that reaction with sodium hydroxide produced hydrogen. Some suggested that all three reacted with Na_2CO_3 , but that the stronger an acid is, the more CO_2 is evolved, or the faster it is evolved.

Question 5

- (a) In general this was a poorly answered part. A one-stage test able to be carried out in a test tube was required. Only the able candidates knew that iodine and sodium hydroxide solution could be used to distinguish between the two isomers. An acceptable alternative was the Lucas test, in which the secondary alcohol **H** would produce a cloudy mixture with $\text{ZnCl}_2 + \text{conc HCl}$ faster than the primary alcohol **L**. The most common incorrect responses involved the use of potassium manganate(VII), potassium dichromate(VI) or 2,4-DNP.
- (b) This was usually well answered although some candidates either did not explain why the presence of chlorine atoms has this acid-enhancing effect (due to their electronegativity, or inductive effect), or referred to the presence of chloride ions.
- (c) This part produced some good answers. The two most common errors were either the omission of water as a product from the equation, or the drawing of a line to represent a covalent bond between the sodium and oxygen in the displayed formula.
- (d) Most candidates were able to draw the structure of the zwitterion correctly, although several thought its formula was $^+\text{NH}_4\text{CH}(\text{CH}_3)\text{CO}_2^-$.
- (e)(i) Most candidates correctly identified the peptide or amide link. Responses that received no credit included *covalent* and *hydrogen*.
- (ii) This was quite well done, although many candidates failed to draw the displayed formula showing the two C=O groups. Some drew a 2-peptide-residue part-structure of a polypeptide.
- (f)(i) Very few candidates gave the correct answer of *benzoyl chloride*, or $\text{C}_6\text{H}_5\text{COCl}$. The common (incorrect) response was *benzoic acid*. Other wrong responses included oxidising agents or reducing agents. Concern has been expressed by a few Centres that this part required the candidates to know what *glycine* was. Examiners looked carefully at candidates' answers to this and to part (ii), and found very little evidence of confusion.
- (ii) Most candidates usually scored 1 mark for correctly naming a suitable reagent. However, far fewer realised that the materials should be refluxed/heated in aqueous/dilute solution. Here again, answers sometimes included oxidising agents or reducing agents.

Question 6

- (a)(i) Most candidates correctly wrote the equation for the decomposition of limestone on heating. Some candidates, however, thought oxygen was a reactant; others split calcium carbonate into its elements.
- (ii) This part was not quite as well answered as part (i). A significant number of candidates wrote an equation in which calcium carbonate was reacted with water to give calcium hydroxide and carbon dioxide.
- (b) This part was answered well. Weak candidates thought the product of the process was used as a fertiliser, or even “to kill insects and germs”, or “to combat earthworms”. Some candidates confused *lowering* the pH of the soil with removing acidity. The statement “to control acidity” was not adequate.
- (c) Many candidates appeared to think that *increasing stability down the group* meant that the carbonates became more reactive, attributing the trend in the properties of the metallic elements to their compounds. Some referred to an increase in *atomic* radius, rather than ionic radius, and others contradicted themselves by suggesting that as ionic size increased the charge density also increased. A *decrease* in stability was often justified by the suggestion that the bond between metal and carbonate was weaker further down the group, so the carbonate decomposed more easily. Some candidates merely referred to the decreasing polarising power of the cations, without explaining that it was the carbonate anion that was suffering polarisation, and hence eventual decomposition.

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| <p>Paper 9701/05</p> |
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| <p>Practical Test</p> |
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General comments

The Examiners thank Supervisors who provided results for the experiments as these were used in assessing accuracy marks for the practical work of each candidate.

The Examiners also thank Centres who provided full information with regard to candidates in each session and laboratory. There are boxes on the front of the Question Paper for this information but they were not always completed. Centres were asked to provide separate Supervisor data for the experiments carried out in each session and each laboratory. Without this information Examiners may not notice any variation between materials used in different laboratories, and candidates may be disadvantaged.

Centres are reminded that they should provide a seating plan for each laboratory.

There was no evidence of lack of time to complete the Paper.

Comments on specific questions**Question 1**

The practical exercise involved weighing, and measuring temperature changes when the weighed solid was reacted with a measured volume of acid.

The Examiners are pleased to report that nearly all candidates recorded their weighings to at least 2 decimal places. The apparatus requirement in the Syllabus is for balances able to read to 0.01 g or better. The Examiners were checking that the weighings were recorded to 2 or more decimal places.

The thermometers specified for the experiments were -10°C to 110°C graduated by 1°C . Centres are reminded that Examiners expect candidates to read calibrated apparatus to the nearest half of a scale division. For the thermometers specified a decimal place should therefore be shown – e.g. 20.0°C ; 20.5°C ; 21.0°C .

Experiment 1

One mark given if the weighings in Table 1.1 were to 2 decimal places; the temperatures in Table 1.2 to 1 decimal place and the subtraction correct in each table. Many candidates lost this mark by recording whole numbers only for one or both temperatures. Candidates who attempted to read the thermometer to better than 0.5°C were not penalised.

Accuracy marks

The Examiners calculated the ratio $\frac{\text{temperature rise}}{\text{mass of FB 2}}$ for each candidate and compared the value obtained (correct to 2 decimal places) with that obtained from the Supervisor's results

Up to 4 accuracy marks were awarded on a widening sliding scale, marks awarded decreasing as the difference between the candidate's ratio and the Supervisor's ratio increased.

- (a) Most candidates gained the mark for (volume of solution x 4.3 x temperature rise) and a correct unit (J or kJ). Any +/- sign given at this stage was ignored.

Some candidates used the mass of **FB 3** in the equation – either on its own or added to the volume of solution. A few did not gain this mark as they used 4.2 as the specific heat capacity of the solution rather than the 4.3 J. cm⁻³ given in the question.

- (b) To gain this mark, candidates had to correctly calculate the moles of hydrochloric acid and sodium carbonate used in the reaction and make reference to the 2:1 ratio of HCl:Na₂CO₃. The majority correctly stated that HCl was in excess – some did not gain the mark as the 2:1 ratio was not stated but assumed.

- (c) Nearly all candidates gained 1 mark by dividing their answer to (a) by the moles of Na₂CO₃. (Divided by 0.5 x moles of HCl if sodium carbonate was considered to be in excess in (b)). The second mark was missed by many as the sign for ΔH was incorrect or missing; mol⁻¹ was missing in the unit or the answer was not correct to 3 significant figures for the calculation.

The Examiners checked the calculation using the numerical values in the expression shown or the answer to (a) divided by moles of sodium carbonate carried in calculator memory from (b).

Where the first mark was not awarded the second mark could still be gained providing the answer to (a) was divided by a mole quantity of HCl Na₂CO₃.

Experiment 2

Tables 1.3 and 1.4 were marked in the same way as Tables 1.1 and 1.2 and the same comments apply.

Accuracy marks

The Examiners calculated the ratio $\frac{\text{temperature decrease}}{\text{mass of FB 3}}$ for each candidate and compared the value obtained (correct to 2 decimal places) with that obtained from the Supervisor's results.

Up to 4 accuracy marks were awarded on a widening sliding scale, marks awarded decreasing as the difference between the candidate's ratio and the Supervisor's ratio increased.

- (d) This was marked in the same way as (a). A missing or incorrect unit was not penalised if it had already been penalised in (a). The same errors in calculations were generally seen as in (a).

- (e) Most candidates gained the mark for dividing their mass of NaHCO₃ by 84.

- (f) Most candidates gained the first mark for dividing their answer to (d) by their answer to (e). The second mark was awarded as in (c). A missing mol⁻¹ was not penalised again but J/kJ, sign and 3 significant figures were required.

- (g) One mark was awarded to any candidate who used ΔH_1 and $2\Delta H_2$ in the answer. A further mark was awarded for $\Delta H_1 - 2\Delta H_2$. Units were ignored in this answer.

Many candidates failed to use $2\Delta H_2$ or added ΔH values.

A number of candidates made no attempt at this part of the question.

Assessment of planning skills

A number of candidates made no attempt at this part of the question. Three or four marks were regularly awarded for the plan.

To gain the first mark a method involving weighing a sample; adding to a measured volume of water and measuring the temperature change was needed. This mark was awarded from the plan on page 6 or from the Table of Results on page 7.

Marks two to four were only awarded for working with the numerical values of an experiment:

- calculating the energy change in the solution;
- calculating the moles of NaHCO_3 (not Na_2CO_3) used;
- calculating ΔH_4 for the reaction - with correct sign (units were ignored).

The final mark was given for adding $2\Delta H_4$ to the answer in (g) (again units were ignored). This mark was obtainable from theory if the experiment had not been carried out. The final mark was awarded infrequently.

Question 2

Assessment of planning skills

This question produced the full range of marks available. Many candidates missed the instruction that the plan should involve the minimum number of steps and reagents to positively identify the substance present in each of **FB 5**, **FB 6** and **FB 7**. As each of the named substances was a nitrate any test carried out to identify the nitrate was ignored.

The Examiners expected to see one reagent added to all three solutions and one of the cations (Al^{3+} , Pb^{2+} , Zn^{2+}) identified from the results of the tests.

The second reagent was only to be added to the two solutions where the cations remained to be identified. An example is given below:

Hydrochloric acid was added to all three solutions. (one mark)

Al^{3+} and Zn^{2+} would give no precipitate but Pb^{2+} would give a white precipitate.

FB 5 and **FB 6** gave no precipitate. (one mark for observation)

FB 7 gave a white precipitate. **FB 7** was therefore identified as containing Pb^{2+} ions. (one mark for observation and explanation)

Aqueous ammonia was then added to the two solutions that gave no precipitate with HCl . (one mark)

This mark was not awarded if the second reagent was added to all three of the solutions.

Both would give a white precipitate but only the precipitate formed with Zn^{2+} would be soluble in excess sodium hydroxide.

FB 5 gave a white precipitate soluble in excess aqueous ammonia.

FB 5 was therefore identified as containing Zn^{2+} ions.

FB 6 gave a white precipitate insoluble in excess aqueous ammonia.

FB 6 was therefore identified as containing Al^{3+} ions. (one mark for complete observations and explanation for each ion)

The explanation of the test results could be found as "theory" in the plan on page 8 or as a deduction with the observations on page 9.

It was not sufficient to state the reagents to be added and name the ions in the final table as it was a planning exercise.

The use of additional reagents, e.g. sodium carbonate to produce effervescence with aluminium nitrate to confirm **FB 6** as containing Al^{3+} was penalised with one mark deducted from the total scored for the question. Each additional reagent was subject to a one mark penalty.

The most common use of an incorrect and additional reagent was to start with aqueous sodium hydroxide; to complete the test and then discover that nothing had been identified as there were three white precipitates each soluble in excess of the sodium hydroxide.

The candidates who scored full marks for the question were usually those who produced a very succinct plan or a precise but comprehensive table of results (and deductions).

Paper 9701/06

Options

Comments on specific questions

Biochemistry

As in previous years this was a popular option and candidates were, on the whole, well prepared.

Question 1

- (a) Most candidates were able to state that lysozymes were enzymes, although relatively few went on to say that they were globular proteins.
- (b) Many candidates scored at least three of the marks, clearly understanding the breakdown products of the various molecules,
- (c) Many could draw the required structures.
- (d) Caused some candidates difficulty, with hydration being the most common wrong answer.

Question 2

- (a) Candidates scored reasonably on this part of this question although in quite a lot of cases the logic of their answers was often difficult to follow. The most common reason for losing marks was because candidates did not relate their points to the data provided.
- (b) A surprising number of candidates dropped marks in this part with many stating that AUG or GUG coded for the first amino acid.

Environmental Chemistry

This option proved more popular this year, and many of the answers were of a reasonable standard, although many lacked detail.

Question 3

- (a) Although some candidates had a good knowledge of the structures of both pyrophyllite and mica, many did not have enough detailed knowledge to score more than a couple of marks.
- (b) The ionic chemistry tested was again often weak for some candidates, with few giving a balanced equation in part (ii). The chemistry of cation exchange sites was rarely well explained.

Question 4

- (a)(i) Required candidates to examine and comment on the chemistry of waste treatment. Few candidates gave sufficient detail in their answers to score more than a mark.
- (ii) A significant number of candidates did not know the role of Al^{3+} in precipitating suspended organic matter before chlorination.
- (b) The role of phosphates in softening water was not well understood, and although many candidates clearly knew about eutrophication, a significant proportion talked about high concentrations of phosphates damaging clothes!

Phase Equilibria

This remains a very popular option and once again produced some very good answers.

Question 5

- (a) The phase diagram of water was generally well known, producing good marks in this part of this question.
- (b) Was less well answered, with most candidates correctly showing the sodium chloride lines, but few drawing a pressure line to show the lowering of freezing point and elevation of boiling point.
- (c) Poorly answered, with very few candidates scoring more than one mark. A surprisingly large number of candidates answered in terms of reduced access of water molecules to the surface of the water, rather than the attraction of the sodium and chloride ions.

Question 6

In this question, most candidates could correctly sketch the boiling point/composition curve for the system.

- (b) Some candidates confused the position of the 40% line, and others did not seem to know how to construct lines to show the first distillate.
- (c) Most candidates could state Raoult's law, but comments on the deviation shown by the nitric acid/water system were often weak.

Spectroscopy

Although one of the less popular options, there were some very well prepared candidates who scored good marks.

Question 7

- (a) Candidates' understanding of the principles of nuclear magnetic resonance seemed to be rather sketchy, and although this question has not been asked for sometime, it was hoped that the principles would have been learned thoroughly. Part (ii) was rather better answered with candidates focusing on the specific example.
- (b) A significant number of candidates ignored the integration values and as a result identified the compound as butan-1-ol instead of 2-methylpropan-1-ol.

Question 8

On the whole this question produced better marks than **Question 7**.

- (a) Candidates used the information sensibly, with a pleasing number scoring full marks.
- (b) The answers to part (b)(i) were also generally good, but in part (b)(ii) almost all the candidates seemed to think that all you needed to do was to put a sample into an atomic absorption spectrometer with no consideration of dilution or calibration.

Transition Metals

This remains a very popular option, although this year there seemed to be some disappointing answers.

Question 9

Most candidates were able to explain the reasons for transition metal compounds being coloured, although there were still a number of candidates who referred to colour being emitted!

- (b) Generally well-answered, although a significant number of candidates thought that the vanadium was being oxidised.
- (c) Did not prove a significant hurdle.
- (d) In contrast this part was low scoring. Candidates seemed unable to use the E^\ominus data to get started, and the titration calculation was frequently incorrect.

Question 10

- (a) Candidates' knowledge of alloys proved to be weak with few candidates scoring both marks.
- (b) Many candidates ignored the instructions to write relevant equations and lost several marks. Although the qualitative descriptions were often correct, the lack of equation and incorrect formulae often meant that only one or two marks were scored.
- (iii) Most candidates understood that the compounds were ionisation isomers.

Paper 9701/08
Practical Test (Mauritius Only)

General comments

The Examiners thank Supervisors who provided results for the experiments as these were used in assessing accuracy marks for the practical work of each candidate.

The Examiners also thank Centres who provided full information with regard to candidates in each session and laboratory. There are boxes on the front of the Question Paper for this information but these were not always completed. Centres were asked to provide separate Supervisor data for the experiments carried out in each session and each laboratory. Without this information Examiners may not notice any variation in solution concentration or other variable between laboratories, and candidates may be disadvantaged.

Centres are reminded that they should provide a seating plan for each laboratory.

The Paper was tackled successfully by most candidates and there was no evidence of lack of time to complete the Paper.

Comments on specific questions

Question 1

The practical exercise was a back-titration to find the relative atomic mass of a metal X contained in its oxide. A sample of the oxide was weighed, dissolved in hydrochloric acid of known concentration and the solution made up to 250 cm³ volume in a graduated flask by addition of further acid. 25 cm³ portions of this solution were titrated with 0.100 mol dm⁻³ sodium hydroxide solution.

The majority of candidates produced a consistent set of titration results but there was a greater than usual range of titre results within each Centre. This would suggest that the preparation of the solution **FC4** introduced errors. The results for some candidates suggested that distilled water rather than more acid (**FC2**) had been added in making the solution up to 250 cm³.

- (e) Most candidates were able to correctly divide their answer to (d) by 2 to calculate the moles of XO that reacted.
- (f) A few candidates gave up at this stage but the majority correctly divided the mass of XO used in the experiment by the answer to (e) to give M_r for the oxide XO. One mark was given if the expression was evaluated.

Some candidates left M_r as the final answer. The second mark was given for subtracting 16 from M_r to find A_r for the element X.

Candidates with errors in earlier steps of the calculation who calculated an M_r value of under 16 seldom looked back at their working to find the error. Examiners would have awarded the final mark to any candidate who stated that 16 had to be subtracted to find the value of A_r - even if this produced a negative value.

Question 2

The aim of the experiment was to verify the equation for the thermal decomposition of sodium hydrogen carbonate by weighing a sample of the salt before and after heating.

One mark was awarded if all of the weighings in Tables 2.1 and 2.2 were recorded to 2 decimal places. This mark was awarded to nearly all candidates.

A second mark was awarded if there was evidence in Table 2.2 of heating and weighing being continued to constant mass. Final weighings within 0.05 g were accepted as "constant" given the time constraints of the examination.

An instruction on the Paper clearly stated:

"Continue the heating and weighing until you are satisfied that decomposition is complete."

In Table 2.2 space was left against "Mass of boiling tube + **FC 5** after heating" for the recording of several results.

It was very unusual to see any candidate who re-heated the tube or who recorded the results of repeated heating. The concept of "heating to constant mass" does not appear to be understood by the majority of candidates.

Accuracy marks

After correcting any subtraction errors in Tables 2.1 and 2.2, the Examiners calculated the ratio:

$$\frac{\text{mass of solid remaining after heating}}{\text{mass of FC 5}}$$

for each candidate and compared the value obtained (correct to 3 decimal places) with that obtained from the Supervisor's results. Sodium hydrogen carbonate should give a value of 0.631 and this or an average derived from the candidates' results was used as a standard value.

- (a) Many complicated calculations were seen – candidates calculated the theoretical mass loss for the mass of **FC 5** used in their experiment and then calculated the % loss, getting the correct answer of 36.9%.

The Examiners had expected to see a simple calculation using molar masses from the equation -

$$\frac{62}{168} \times 100\%$$

A common error was to ignore the carbon dioxide given off and calculate the % of water evolved on heating.

Some candidates worked with their practical results and calculated the % mass loss for their experiment at this stage.

- (b) Nearly all candidates correctly calculated the % loss in mass during the experiment.
- (c) Many candidates did no more than indicate yes/no in this section. To gain the mark there had to be an explanation of the difference that fitted the observed difference.

If (a) > (b) the Examiners were looking for an answer such as:

The solid absorbed moisture from the air on cooling.

If (b) > (a) the Examiners were looking for an answer such as:

The solid was damp at the start or had absorbed moisture before heating.

The Examiners saw many references to impurities. To gain the mark the impurity had to be stable to heat or unstable to heat as appropriate, the presence of an impurity alone did not gain the mark.

References to insufficient heating were not accepted as the instruction in the Paper had been to continue the heating until decomposition was complete.

The Examiners did allow an insufficient temperature (of the Bunsen flame) to cause complete decomposition if (a) > (b).

Where the answers to (a) and (b) were exactly the same (often because of an incorrect calculation in (a)), the Examiners were looking for an explanation as to possible differences in the values.

Paper 9701/09

Practical Test (Mauritius Only)

General comments

The Examiners thank Supervisors who provided results for the experiments as these were used in assessing accuracy marks for the practical work of each candidate.

The Examiners also thank Centres who provided full information with regard to candidates in each session and laboratory. There are boxes on the front of the Question Paper for this information but they were not always completed. Centres were asked to provide separate Supervisor data for the experiments carried out in each session and each laboratory. Without this information Examiners may not notice any variation between materials used in different laboratories, and candidates may be disadvantaged.

Centres are reminded that they should provide a seating plan for each laboratory.

There was no evidence of lack of time to complete the Paper.

Comments on specific questions

Question 1

The practical exercise involved weighing, and measuring temperature changes when samples of ammonium iodide, with and without impurity were dissolved in water. From a graph of the experimental work candidates were asked to calculate the % purity of the sample containing the impurity.

Two marks were given if the weighings in Table 1.1 were to 2 decimal places; the candidate had indicated a weighed mass between 1.95 g and 2.05 g; and the subtraction was correct. One mark was deducted for each error (no negative marks).

The Examiners are pleased to report that nearly all candidates recorded their weighings to at least 2 decimal places. The apparatus requirement in the Syllabus is for balances able to read to 0.01 g or better. The Examiners were checking that the weighings were recorded to 2 or more decimal places. Most candidates also gained the second mark.

One mark was given if all thermometer readings in Table 1.2 were recorded to 1 decimal place.

The thermometers specified for the experiments were -10°C to 110°C graduated by 1°C . Candidates are reminded that Examiners expect candidates to read calibrated apparatus to the nearest half of a scale division. For the thermometers specified a decimal place should therefore be shown – e.g. 20.0°C ; 20.5°C ; 21.0°C . Candidates who attempted to read the thermometer to better than 0.5°C were not penalised.

A second mark was given for correct subtractions for all Δt values in Table 1.2. This mark was gained by most candidates.

Accuracy marks

For the tube **FD 2**, where ammonium chloride had been weighed by the candidate, Examiners calculated the temperature change if exactly 2.00 g of the solid had been used.

$$\Delta t(\text{standard}) = \frac{2.00}{\text{mass used in Table 1.1}} \times \Delta t \text{ recorded in Table 1.2}$$

This was calculated (correct to 2 decimal places) for each candidate and compared with the value obtained from the Supervisor's results.

Up to 4 accuracy marks were awarded on a widening sliding scale, marks awarded decreasing as the difference between the candidate's ratio and the Supervisor's ratio increased

For each candidate the Δt value for tube **FD 3** was compared to the same value in the Supervisor's results and a further 4 accuracy marks awarded using the same sliding scale.

- (b) One mark was given for a graph where Δt was plotted on the *y-axis* and mass of solid on the *x-axis*. This mark was with-held if units were not given on the axes or less than half the *x-axis* was utilised in plotting points.

A small number of candidates reversed the axes, or used less than half of the *x-axis*. A larger number of candidates omitted units from one or from both axes.

One mark was given for an acceptable straight line drawn through at least three of the plotted points. If the experiment had been performed with precision, four of the points should have been on the straight line, the **FD 4** point being below the line as it contained the impurity.

A small number of candidates plotted curves rather than a straight line – usually as the result of poor practical work.

The Examiners were disappointed to see the large number of candidates who plot graphs by joining all of the points – either with straight lines or a curve that “wanders around” to pass through all of the points.

Examiners were also looking for graphs where the intention appeared to be a straight line but the graph was drawn in sections (usually two), using a short ruler and producing a discontinuity in gradient. Every candidate should have as basic equipment a ruler of sufficient length to draw a single straight line.

The third graphical mark was given for a straight line passing within $\frac{1}{2}$ small square of the origin on either axis. Scales that did not start at (0,0) were not penalised for the first mark but failed to score the third mark.

A minority of candidates scored all three marks for the graph.

- (c) One mark was given for selecting the **FD** tube whose plotted point showed the greatest deviation from the straight line or curve. **FD 4** was as expected the tube selected by the majority of candidates from their practical work. Other tubes were selected at times including some where the plotted point had a greater Δt value than expected from the graph. These were accepted and candidates who had plotted reasonable graphs usually gained this mark.
- (d) One mark was given for a simple explanation that the point was furthest from the plotted line or that the Δt value was lower or higher (as appropriate) than expected.
- (e) Three marks were available in this section for a calculation *based on the graph*.

A few candidates took data from Table 1.2 and scaled the value to find a % purity or % impurity. They were awarded no marks.

The purpose of drawing a graph is to eliminate errors in individual experiments and establish the relationship between the variables.

Data for a point read from the graph (preferably not one of the original plotted points) and scaled appropriately would have scored marks.

One mark was awarded for any clear use of graphical data in the calculation.

The second mark was for precise reading from the graph (within $\frac{1}{2}$ small square) of Δt for 4.00 g of pure ammonium chloride, or the precise reading from the graph (within $\frac{1}{2}$ small square) of the mass of ammonium chloride giving the Δt value plotted on the graph.

The third mark was given for:

$$\% \text{ purity} = \frac{\text{actual } \Delta t}{\Delta t \text{ read from graph for 4.00 g}} \times 100 \quad \text{or} \quad \frac{\text{mass read from graph}}{4.00} \times 100.$$

Where Δt was greater than expected (points above the graph), the % purity calculated was greater than 100%.

Candidates who calculated the % impurity were able to gain the first two marks.

Many candidates missed the second mark by imprecise reading of data from the graph.

A considerable number of candidates did not attempt (e), others used methods involving enthalpy changes, changes on heating and even titration.

Question 2

Assessment of planning skills

The Examiners considered the problem posed in this planning exercise to be straight-forward but in practice the question was not performed well by the majority of candidates. It would appear that the concept of a sequence of steps is not understood, even though the rubric for the question had spelt out in detail the continuation of the tests at each stage. In the light of answers seen, the mark allocation was changed to give 4 marks to Stage 1 and 2 marks to Stage 3.

Candidates who started each test with fresh solution **X** were only able to score marks for Stage 1.

Examiners found the writing of suitable balanced equations to be poor.

Equations at each stage were accepted if the cation was present as the nitrate, a simple ion or a complex ion where appropriate e.g. $[\text{Pb}(\text{OH})_4]^{2-}$. $\text{Pb}(\text{OH})_2(\text{aq})$ was accepted as a "complex ion".

State symbols were ignored.

Stage 1

The only reagent that could be added to precipitate magnesium ions leaving zinc and lead in solution was aqueous sodium hydroxide (one mark), in excess (one mark).

One mark was given for the equation and one mark for filtering the solution.

Many candidates scored 3 or 4 marks for Stage 1.

Stage 2

The filtering mark for Stage 1 was often awarded at this point.

Addition of hydrochloric acid or sulphuric acid to the filtrate from Stage 1 to give a precipitate containing Pb^{2+} was awarded two marks.

An alternative route was to add nitric acid (one mark) to neutralise the excess sodium hydroxide from Stage 1, then to add excess ammonia (one mark) to precipitate $\text{Pb}(\text{OH})_2$.

Many candidates added ammonia directly. $\text{Pb}(\text{OH})_2$ will not precipitate in the presence of excess NaOH . Candidates who added HCl or H_2SO_4 and ammonia were awarded one mark for the initial addition of acid.

One mark was given for an appropriate equation. Some candidates scored 2 or 3 marks for Stage 2.

Stage 3

If the chloride or sulphate had been precipitated in Stage 2, it was necessary to neutralise the excess acid with NaOH /aqueous ammonia or add the alkali until a precipitate appeared.

If the hydroxide had been precipitated in Stage 2 it was necessary to neutralise with an acid or add the acid until a precipitate *of the hydroxide* formed.

Many candidates lost this mark by adding $\text{HCl}/\text{H}_2\text{SO}_4$ and stating that zinc chloride or zinc sulphate would be precipitated.

Adding the reagent to excess was a common mistake – the zinc hydroxide being soluble in excess alkali or acid.

A final mark was given for a correct equation for the precipitation of $\text{Zn}(\text{OH})_2$.

Confirmation of precipitation of lead at Stage 2

Few candidates gained this mark. Many made no attempt, others did not make it clear that the reagent needed to be added to the filtrate after Stage 2. A mark was allowed for adding further aqueous ammonia or excess $\text{HCl}/\text{H}_2\text{SO}_4$ if ammonia alone had been added in Stage 2.