

# CHEMISTRY

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

## General comments

For this paper, the mean score was 23.4 (58.5%), slightly below the targeted value, and the standard deviation of the scores was 7.63 (19.1%), indicating that the paper discriminated very satisfactorily among candidates.

**Questions 1 to 30** were simple completion items.

**Questions 31 to 40** were three-statement multiple completion items.

## Comments on Individual Questions

Only one question had a facility above the design limit. **Question 1** required the calculation of the number of protons, neutrons and electrons in the phosphide ion  ${}_{15}^{32}\text{P}^{3-}$ .

Of the other questions, only one did not perform satisfactorily. **Question 34** was concerned with observations that could be made about the addition of water to anhydrous aluminium chloride to make an

aqueous solution, and it foundered because no less than 61% of candidates, including some of the more able candidates, believed this to be an endothermic reaction. There must be confusion here on the meanings of *endothermic* and *exothermic*, a very basic understanding.

Although they performed satisfactorily, two other questions deserve comment. Both indicated some level of guessing, which is usually associated with an area of the syllabus in which candidates lack confidence: these were the distinctions between the  $S_N1$  and  $S_N2$  mechanisms for nucleophilic substitution of alkyl halides (**Question 25**), and the nature of the attacking species in a nucleophilic addition on a carbonyl group (**Question 28**).

# CHEMISTRY

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Paper 9701/02

AS Structured Questions

## General comments

This paper tested candidates' knowledge and understanding of some of the theoretical aspects of AS Level Chemistry. While there were many good answers to these questions, there were also many candidates who struggled to explain clearly the relevant theory.

In addition, Chemistry has a significant factual content and a number of questions asked candidates to recall knowledge. Again, there were many good answers to these questions but a number of candidates had not learned some basic Chemistry and were therefore penalised. This was particularly true for the last two questions which were concerned with organic chemistry.

Overall, there were many good answers to this paper and most candidates were able to demonstrate some positive achievement.

The handwriting of some candidates continues to cause Examiners some concern. If an answer cannot be read, no marks can be awarded. Similarly, Examiners are concerned by the habit which some candidates have of giving two contradictory answers to the same question. An example of this, in **Question 3(d)(i)**, was "the concentration of  $\text{NOCl}$  increases and the equilibrium moves to the right". Such answers received no credit.

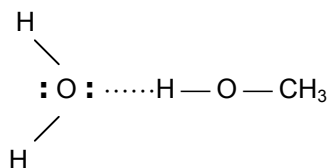
## Comments on specific questions

### Question 1

This question explored candidates' knowledge and understanding of intermolecular forces when applied to both familiar and unfamiliar compounds. **Part (d)** was intended to be demanding, and Examiners were impressed by the answers of many candidates who tried to explain the facts given in the question.

- (a) (i) Most candidates were able to deduce that there are two lone pairs of electrons around the oxygen atom in methoxymethane.
- (ii) Candidates were expected to apply the qualitative model of electron-pair repulsion and deduce, by analogy with water, that the C-O-C bond angle would be between  $104^\circ$  and  $105^\circ$ .
- (b) Although there were many correct answers for each of the four compounds listed, few candidates were able to state correctly the strongest intermolecular force present in all of them. The strongest inter-molecular force is hydrogen bonding which is only present in ethanol. Permanent dipoles are present in both ethanal and methoxymethane, while molecules of 2-methylpropane can only form induced dipoles.
- (c) (i) The majority of candidates correctly identified the intermolecular force as hydrogen bonding.

- (ii) While there were many good diagrams which correctly showed hydrogen bonding between water and methanol molecules, there were a significant number of candidates who gave incomplete or incorrect answers. Common errors were failing to show the dipole in water correctly, or failing to include the lone pairs of electrons which are present on the oxygen atoms of both water and methanol. Examiners expected one lone pair of electrons to be clearly shown in the hydrogen bond as in the example below.



A similar diagram can be drawn using the lone pair of electrons on a methanol molecule.

A small number of candidates failed to include a molecule of methanol, or gave the molecular formula of water as  $\text{HO}_2$  for which they were penalised. Those candidates who thought one of the hydrogen atoms of the methyl group of methanol was involved in hydrogen bonding were similarly penalised.

- (d) Many candidates found this part difficult. In **part (b)**, different types of intermolecular force were listed and Examiners expected candidates to use this list to help them with their answers to **part (d)**. Both water and ethoxyethane molecules have a permanent dipole. Water is a liquid with hydrogen bonds between its molecules. Ethoxyethane, however, cannot form hydrogen bonds between its molecules. These differences in the intermolecular forces present in each liquid help to explain the lack of complete solubility of ethoxyethane in water.

Examiners also gave credit for answers which explained how the hydrophobic nature of the ethyl groups present in ethoxyethane would hinder the dissolving of ethoxyethane in water.

## Question 2

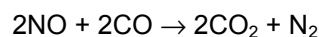
The study of the periodic trends of the elements involves being able to recall knowledge and interpreting data about the elements. In **part (b)**, there were many good explanations of the general trend in ionisation energies of the first 18 elements of the Periodic Table. Answers to **part (c)** were less good, however, with a significant number of candidates rephrasing the question rather than giving a clear explanation. Most candidates were able to complete much of the table in **part (d)** correctly.

- (a) The majority of candidates answered this part correctly. Common mistakes were to use  $\text{F}_2(\text{g})$  rather than  $\text{F}(\text{g})$ , and to form the anion,  $\text{F}^-$ , rather than the cation,  $\text{F}^+$ .
- (b) Most candidates were able to explain the general increase in first ionisation energies by referring to at least two of the changes that are significant: nuclear charge, electronic shielding and atomic radius.
- (c) (i) While most candidates were able to state the correct electronic configurations of Mg and Al, fewer were able to explain the difference in first ionisation energies. A popular wrong explanation referred to the single 3p electron of aluminium being 'more easily removed' – which is exactly what the question said.
- (ii) This part was less well answered. Many candidates were unable to state the correct electronic configurations of the two elements while a significant number tried to explain the difference in terms of shielding. Few candidates correctly referred to the repulsion between the **pair** of electrons in the same p sub-orbital of sulphur.
- (d) Very few candidates scored full marks in this section. The most common error was to state that sodium has a high melting point, while a significant number of candidates thought that silicon has a low melting point.
- (e) A surprising number of candidates did not know that the noble gases were not isolated until after Mendeleev first drew up his Periodic Table.

**Question 3**

The first part of the question concerned an important aspect of environmental chemistry and was generally well answered. The calculation in **part (c)** was correctly done by the majority of candidates, but there were relatively few correct answers to **part (d)**.

- (a) Most candidates understood that the reaction in the car engine occurs at a higher temperature than that in the laboratory. Fewer went on to explain how this higher temperature would provide the activation energy needed to break the strong N≡N bond.
- (b) (i) Pollutants that were accepted were C, CO, unburned hydrocarbons, SO<sub>2</sub>, H<sub>2</sub>S and NO<sub>2</sub>/NO<sub>x</sub>. Examiners did not accept CO<sub>2</sub>, H<sub>2</sub>, H<sub>2</sub>O, SO<sub>3</sub> or NO, the latter having been mentioned in the question.
- (ii) This was generally well answered with candidates generally choosing platinum or palladium, often in combination with rhodium. Some carelessness was evident in candidates' answers to this part, two typical wrong answers being 'plutonium' and 'rubidium'. Candidates are always advised to check their work carefully.
- (iii) Many candidates gave a correct equation such as



Those candidates who stated that NO<sub>2</sub> would be produced in the catalytic converter received no credit. The principle of such exhaust systems is that NO is reduced to N<sub>2</sub> by a pollutant such as CO, which is in turn oxidised to CO<sub>2</sub>. The resulting exhaust gases are less polluting, and certainly less toxic, than the NO/CO mixture.

- (c) (i) Most candidates were able to give the correct expression for  $K_c$ , as shown below. A significant number failed to give units, as the question required.

$$K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} \quad \text{units are mol dm}^{-3}$$

Those candidates who used curved brackets, as in (NO)<sup>2</sup>, rather than square brackets as above, were penalised.

- (ii) Many candidates calculated both values of  $K_c$  correctly. These are as follows.

$$\text{at } 230 \text{ }^\circ\text{C} \quad K_c = 4.5 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{at } 465 \text{ }^\circ\text{C} \quad K_c = 9.2 \times 10^{-2} \text{ mol dm}^{-3}$$

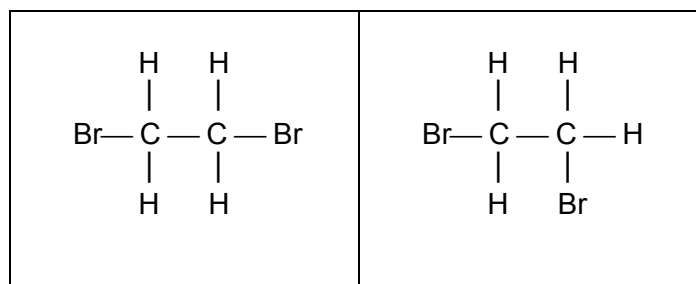
- (iii) Fewer candidates were able to state correctly that the forward reaction is endothermic **and** explain why. In order to avoid giving marks for a guess which has a 50% chance of success, Examiners only gave credit for those answers which correctly explained that the value of  $K_c$  increases as the temperature rises.
- (d) (i) The majority of candidates failed to explain clearly that the forward reaction involves an increase in the number of molecules, from two to three, so that if the pressure of the system at equilibrium is halved, the forward reaction will be favoured.
- (ii) Very few candidates were able to make any worthy comments in this part. A straightforward answer is that, when equal numbers of moles of both NOCl and NO are added to the equilibrium, the position of equilibrium will not change. Examiners were prepared to give credit for more sophisticated answers that dealt with changes in concentration or pressure caused by more molecules being present in the closed system.

**Question 4**

The understanding of molecular structure and of isomerism is an important part of the study of AS Level and A Level Chemistry. While many candidates scored reasonable marks on this question, relatively few were given the maximum.

- (a) (i) Most candidates were able to draw correctly the displayed formulae of the two isomers of  $C_2H_4Br_2$ , i.e. 1,1-dibromoethane and 1,2-dibromoethane.

The most common error was to give two structures for 1,2-dibromoethane in which the Br atom appears to be in a different place, as shown below.



The use of simple molecular models helps candidates to understand the three dimensional nature of such molecules and that there is free rotation about the C-C bond.

- (ii) This was generally well answered.
- (b) (i) The majority of candidates knew the reagent to be hydrogen. Fewer were able to state that the reaction is done catalytically, usually with nickel as the catalyst.
- (ii) Many candidates struggled with this part, usually stating that hydrogen is added across the C=C bond. The crucial difference is that the *cis* isomer of  $C_2H_2Br_2$  has one bromine atom attached to each carbon atom so that when it is hydrogenated, 1,2-dibromoethane will be formed.

**Question 5**

This question tested candidates' knowledge and understanding of the reactions of carbonyl compounds as applied to the unfamiliar compound ethanedial. While there were many good answers, few candidates scored full marks.

Although several parts of the question asked for structural formulae, many candidates chose to give displayed formulae. This was a sensible choice when one considers the complexity of some of the molecules concerned. Examiners accepted either type of structure.

The most common error in the structures was to draw one of the hydroxyl groups wrongly.

Candidates who drew a structure containing  $\text{OH}-\overset{\textstyle |}{\text{C}}-$  rather than  $\text{HO}-\overset{\textstyle |}{\text{C}}-$  were penalised.

Details of how candidates are expected to draw structures are given in **section 10.1** of the syllabus.

- (a) (i) The majority of candidates answered this correctly.
- (ii) Fewer candidates knew that the compound formed would be ethanedioic acid.
- (b) Knowledge of the mechanism of the reaction between a carbonyl compound and HCN is a requirement of **section 10.5(b)** of the syllabus. Despite this, many candidates gave poor answers to **parts (i) and (ii)**.
- (i) The most common error in the structure of the cyanohydrin formed was to omit the  $-\text{OH}$  group.
- (ii) A surprising number of candidates failed to identify the reaction as 'nucleophilic addition'.

- (iii) Relatively few candidates knew that the reaction of the cyanohydrin with dilute sulphuric acid will produce the corresponding carboxylic acid.
- (c) (i) Most candidates correctly gave 'ethanedioic acid' as their answer. The most common mistake was by those candidates who failed to realise that, by using an excess of reagent, both carbonyl groups would be oxidised.
- (ii) Many candidates were able to identify the correct product of reduction which is  $\text{HOH}_2\text{CCH}_2\text{OH}$ . Since an excess of reagent was not mentioned in the question, Examiners accepted the compound  $\text{HOH}_2\text{CCHO}$  as a correct answer.
- (iii) A variety of reducing agents can be used for this reduction. Popular choices were  $\text{NaBH}_4$  and  $\text{LiAlH}_4$ . Examiners penalised those candidates who mentioned using  $\text{LiAlH}_4$  in aqueous solution.
- (d) The unusual reaction in this part involves both oxidation and reduction, one  $-\text{CHO}$  group being oxidised and the other being reduced. Many candidates deduced this correctly.
- (e) Few candidates were able to deduce a correct structure for the isomer. Since hydrogen is produced with sodium, the compound must contain an  $-\text{OH}$  group. The compound in question was actually  $\text{HO}-\text{C}\equiv\text{C}-\text{OH}$ .

# CHEMISTRY

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**Paper 9701/031**  
**Advanced Practical Skills 1**

## General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data and seating plans for each session/laboratory. If candidates are not to be disadvantaged, it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and a corresponding set of Supervisor results. Regrettably a number of Centres failed to provide this Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence. Some other Centres provide Supervisor data for multiple sessions/laboratories, but give insufficient data to place candidates within each session, and again candidates may be disadvantaged.

Instructions were given in the Confidential Instructions for the preparation, checking of concentration and storage of the hydrogen peroxide. It became apparent that these instructions had not been followed in a number of Centres, resulting in unexpected titre values. This led to potential problems, as the Examiners only expected one titration to be performed at each stage, and had indicated in **parts (a) and (b)** the approximate end-point for each titration using the correctly prepared solutions. As one "accurate" titration was sufficient, the Examiners described in the question paper the colour changes to be seen in the solution as the end-point was approached.

In **Question 1** many candidates either did not follow the instruction to read through the question before starting practical work, or did not refer back to the initial information later in the question, as many of the instructions for the practical were ignored.

## Comments on specific questions

### Question 1

This question was similar in form to that set in November 2007, involving decision making as to the spread of experiments to be performed and the display of results in a graphical form.

- (a) In most Centres the titre value closely matched that obtained by the Supervisor. Marks were awarded in this section for titres within  $0.20 \text{ cm}^3$  of the Supervisor and for a difference of  $0.20+ \text{ cm}^3$  to  $0.50 \text{ cm}^3$ . There was also an additional "quality" mark available.
- (b) Where the hydrogen peroxide solution had been correctly prepared most candidates obtained titres close to the titre obtained by the Supervisor. There was some evidence of poor storage within laboratories with very variable titres as the peroxide decomposed.
- (c) The Examiners had not anticipated that few candidates would be able to perform this calculation. The majority of candidates calculated  $((\mathbf{a}) - (\mathbf{b})) + 12 \text{ cm}^3$ . This gave an answer of the expected magnitude.

More able candidates were able to calculate  $\frac{\text{titre } (\mathbf{a})}{(\text{titre } (\mathbf{a}) - \text{titre } (\mathbf{b}))} \times 12 \text{ cm}^3$ .

Some candidates arrived at the correct answer by using calculations involving the concentration of  $\text{Fe}^{2+}$  ions, and others derived the answer from the gradient on the diagram on page 2.

- (d) This section involved a number of the skills specified in the current practical syllabus which do not yet appear to be fully appreciated by the candidates. Six marks were available in this section.



Candidates were expected to produce a **single table**, recording the volume of **FA 3** added, initial and final burette readings and the titre. A single table has no repetition of headings, e.g. initial burette reading or final burette reading. They were then to prepare **the table of results before carrying out the experiment**. Candidates were expected to include information from **(a)** and **(b)** in this table. As evidence that the table had been drawn up in advance of the experiment, the Examiners expected to see the volumes of **FA 3** used in sequential order (ascending or descending). The data from **(a)** and **(b)** could be included at the beginning or end of the table, or in the sequential order. Many candidates failed to include the data for **(a)** and **(b)** in the table.

The table should include **correct headings and units**. The attention of Centres is drawn to the description of acceptable units in the practical section of the syllabus. Where a unit of volume is included in the column heading it must be shown:

with the solidus, /  $\text{cm}^3$ ; in brackets, ( $\text{cm}^3$ ); or in words, **volume in cubic centimetres**.

Many candidates failed to display one or more units correctly. Where the unit was not included in the column heading, every entry in the table required  $\text{cm}^3$  to be added. It was very common to find at least one volume recorded with the unit omitted.

As instructed, candidates were expected to select four additional volumes of **FA 3** to be added in further titres. Many candidates who included **(a)** and **(b)** in the table only selected two further volumes of **FA 3**, giving a total of four (rather than six) titres.

The volumes should have been recorded **with the precision capable from a burette**. It was expected to see all burette readings and the volumes added recorded to the nearest  $0.05 \text{ cm}^3$ . This included the volume of **FA 3** added, as it was measured with a burette. It was pleasing to note that the number of candidates who claim to be able to read a grade B burette to  $0.01 \text{ cm}^3$  is diminishing.

A **decision mark** was available for selecting appropriate volumes of **FA 3** to enable the graph shown on page 2 to be drawn. Candidates were reminded that they had two values on the left-hand line (**(a)** and **(b)**) and were told the approximate volume of **FA 3** to give point **Z** if unable to determine a value in **(c)**. They were also told to add no more than  $40.0 \text{ cm}^3$  in any single titration.

The majority of candidates did not select volumes of **FA 3** that would enable them to plot the right-hand line, i.e. few volumes of **FA 3** greater than  $20 \text{ cm}^3$  were selected. The Examiners were looking for one additional point to the left, and three to the right of **Z**, or two points on either side of **Z**. Where three additional volumes only were selected, the spread had to be one point to the left and two to the right.

Two common errors seen in candidates' answers were to:

- bunch all of the additional volumes around  $19 - 21 \text{ cm}^3$  of **FA 3**,
- include  $20 \text{ cm}^3$ , with a titre close to zero, as one of the volumes of **FA 3**.

- (e)** A significant number of candidates failed to label the axes and/or selected inappropriate scales that made accurate plotting of points difficult, as a calculator had to be used to work out the actual position of a point on the graph paper.

Many candidates did not take sufficient care when placing the centre of a point on a graph. The Examiners were checking points to within half of a small square in either direction, providing the point was within the "correct" square. Crosses drawn with blunt pencils or large "blobs" are not satisfactory points in this examination. If the centre of a point should be on a line of the graph paper, Examiners would like to see the centre of the plotted point on that line not to one side of it. Similarly, points that are not on a line should not be plotted on a line. Points are checked to the nearest half of a small square but candidates should be able to work to a quarter of a small square or better.

Because most candidates selected volumes of **FA 3** that were to the left of **Z** they were unable to draw appropriate lines. Two points minimum were required on either line with the intersection on the x-axis.

The value of the intersection of two lines, read from the x-axis, was allowed even if the lines drawn did not meet on the x-axis. Where candidates had all of their points on the left-hand line, the intersection of this line with the x-axis was also allowed.

As a very large number of candidates had a single left-hand line one of the available “quality” marks originally assigned to this section was moved to **part (a)** as already mentioned. Examiners considered the best-fit left-hand line where there were three or more plotted points and gave credit for points very close to a straight line, i.e. for consistent practical work.

- (f) Many candidates failed to indicate a point where they considered a repeat titration to be needed or having circled the point (as instructed), failed to explain why a repeat titration was necessary. Left- and right-hand lines had to be drawn with some supporting plotted points for each line.

### Calculations

Most candidates who attempted any calculation were credited for showing working, but far fewer candidates showed appropriate (three or four) significant figures in their answers in **parts (g)** and **(h)**.

- (g) Many candidates failed to correctly calculate the relative formula mass for the hydrated ammonium iron(II) sulphate. The formula of the compound was given on page 2 and the appropriate relative atomic masses in **part (g)**. It was important that 32.1 for sulphur and 55.8 for iron were used when calculating the formula mass.

Many candidates correctly calculated the moles of  $\text{Fe}^{2+}$  pipetted into the flask, but displayed their answer as  $1 \times 10^{-3}$ , losing the significant figure mark as a consequence.

- (h) Most candidates who had recorded an intercept volume in **(e)** correctly calculated the moles of **X** present in the volume of **FA 3** represented by **Z**.
- (i) Candidates who had answers to **(g)** and **(h)** were generally able to calculate:

$$\frac{\text{answer to (g)}}{\text{answer to (h)}}$$

but a number of these missed the instruction to give the answer to 3 significant figures.

A few inverted expressions were seen.

### Question 2

Candidates should appreciate that reagents are compounds (silver nitrate or lead nitrate) and not just ions ( $\text{Ag}^+$  or  $\text{Pb}^{2+}$ ), even when one of the ions present in the reagent is the “active” part of the reagent.

On this occasion, Examiners accepted named and appropriate aqueous ions or solutions containing those ions as reagents. Where incorrect formulae were given for a selected reagent but the intended reagent was clear to the Examiner, the identity of the reagent was allowed. In the conclusion **part (f)**, however, any formula for the ions or compound present and for the reagents used had to be correct to gain marks.

- (a) Most candidates scored well in this part, selecting silver nitrate followed by aqueous ammonia or silver nitrate and lead nitrate used in separate tests. Observations for both reagents were needed but the conclusion was allowed from a correct observation with a single reagent.
- (b) Many candidates did not report their initial observation followed by the observation when sodium hydroxide was added to excess. It is not sufficient to report a white insoluble hydroxide. Examiners expect to see an observation of a white precipitate soluble or insoluble in excess, as in the notes on page 11.
- (c) As in **(b)** above.
- (d) Most candidates gained the mark for no precipitate with **FA 4** in tests **(b)**, **(c)** and the first part of **(d)**.

The majority of candidates scored the mark for a white precipitate with barium chloride that was insoluble in hydrochloric acid.

Some candidates however did not make it clear that the precipitate remaining in the solution after adding hydrochloric acid was the precipitate formed with the barium chloride. Their answers left it unclear as to whether a new precipitate formed on adding the hydrochloric acid.

- (e) This section was a test of technique and careful observation. Nearly all candidates reported the yellow precipitate on adding lead nitrate to **FA 4**. Very few candidates noticed the solubility or partial solubility of the solid on heating the solution containing the precipitate, or the formation of crystals on cooling the solution. A shiny or glittering precipitate was accepted as crystal formation. Formation or reappearance of the precipitate on cooling was also allowed.

The mark for this section was gained from the initial observation of a yellow precipitate coupled with either of the solubility on warming / reforming of precipitate on cooling observations.

- (f) Many candidates failed to gain marks in this section by giving incorrect formulae. It is safer to name compounds if there is uncertainty about giving a correct formula.

The rubric specifically states that no further tests for ions should be performed. Many candidates claimed to have detected ammonia from sodium hydroxide and **FA 4**. This solution was intentionally sodium iodide to lead in to the question in (g). (The Confidential Instructions remind Centres that the identity of a compound/solution may differ between the Instructions and the question paper).

By “testing” for the ammonium ion, candidates forfeited the mark in this section for ions that had not been specifically identified. Lead ions were not permitted as an alternative in **FA 5** as the cations present had been clearly stated at the beginning of the question.

Two pieces of evidence for iodide ions were required for **FA 4**, evidence for aluminium and sulphate ions for **FA 5** and evidence from the reaction with aqueous ammonia in excess for zinc ions in **FA 6**. The Examiners expected ammonium and nitrate ions to be the pair selected as not specifically identified.

Many candidates were inaccurate in presenting their evidence, e.g. “white precipitate with barium” (rather than with barium chloride or barium ions), “it was soluble in ammonia solution” (the “it” not being defined), or “zinc is soluble”.

- (g) Very few candidates gained the mark in this section. Most chose to repeat the information given in the notes on pages 11 and 12.

There was a very common misconception that ammonia is evolved on heating an ammonium salt giving no mention of heating with sodium hydroxide.

Many candidates simply stated that it was easier to test for ammonium ions than to test for nitrate ions.

The Examiners were expecting candidates to realise that if they tested for nitrate ions first the sodium hydroxide present would also react with any ammonium ions present. Any resulting ammonia gas detected could have come from either the ammonium ions or the nitrate ions. The solution should therefore be heated with sodium hydroxide and tested for the evolution of ammonia gas before adding aluminium foil and testing for ammonia gas again.

# CHEMISTRY

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**Paper 9701/32**  
**Advanced Practical Skills 2**

## General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data and seating plans for each session/laboratory. If candidates are not to be disadvantaged, it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and a corresponding set of Supervisor results. Regrettably a number of Centres failed to provide this Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence. Some other Centres provide Supervisor data for multiple sessions/laboratories, but give insufficient data to place candidates within each session and again candidates may be disadvantaged.

There was little evidence of candidates running out of time.

## Comments on specific questions

### Question 1

**(a) and (b)** Most candidates were credited for showing working in each of these parts, but many candidates who performed correct chemical calculations forfeited a mark because of inappropriate rounding of their answers. The expected volumes were  $31.45 \text{ cm}^3$  or  $31.5 \text{ cm}^3$  in **(a)** and  $19.84 \text{ cm}^3$ ,  $19.85 \text{ cm}^3$  or  $19.9 \text{ cm}^3$  in **(b)** – answers correct to 3 or 4 significant figures. Among the rounded answers seen were  $0.03 \text{ dm}^3$  in **(a)** and  $20 \text{ cm}^3$  in **(b)**.

**(b)** Examiners expected to see all thermometer readings and temperature differences expressed to the nearest  $0.5 \text{ }^\circ\text{C}$ , reflecting the precision of the thermometers specified for the examination. Many candidates were not consistent in recording temperatures or temperature changes.

Some candidates still claim to be able to read a thermometer calibrated in whole degrees to  $0.1 \text{ }^\circ\text{C}$  or even to 2 decimal places.

A small number of candidates recorded very unlikely temperatures, e.g.  $3.2 \text{ }^\circ\text{C}$ . If such temperatures were read as  $32 \text{ }^\circ\text{C}$ , recorded temperature differences matched those for other candidates in the Centre.

Nearly all candidates recorded two temperature readings and a temperature difference for each of the tubes **FB 2**, **FB 3** and **FB 4**. A large number of candidates attached a negative sign to reactions in which the temperature increased and a positive sign when there was a decrease in temperature during the reaction. This suggests that there might have been confusion with the sign for an enthalpy change.

Most candidates recorded all of the data above in an appropriate single table with no repetition of column headings, etc. Some candidates also included the volume of acid in the table, which was an unnecessary addition.

Most candidates gave appropriate headings but units were not always appropriate.

The attention of Centres is drawn to the description of acceptable units in the practical section of the syllabus. Where a unit of temperature is included in the column heading it must be shown: with the solidus,  $/ \text{ }^\circ\text{C}$ ; in brackets,  $(^\circ\text{C})$ ; or in words, **temperature in degrees Celsius**. Many candidates failed to display one or more units correctly.

Where the unit is not included in the column heading, every entry in the table required °C to be added. It was very common to find at least one temperature recorded with the unit omitted.

- (c) A very high proportion of candidates did not realise the importance of the statement in the stem of the question, which referred to each of the prepared tubes containing a total mass of 5.00 g of mixture.

The Examiners were looking for one mixture with a composition between those in tubes **FB 2** and **FB 3** and a second mixture with a composition between those of the mixtures in tubes **FB 3** and **FB 4**. Each tube was allowed to have a total mass between 4.90 g and 5.10 g.

There was no pattern to the mixtures suggested by many candidates. Among the common errors in this section were:

- selection of very large and very small total masses
- mixtures selected with different masses but the same % composition as one or more of the initial tubes
- 100% sodium carbonate and 100% sodium hydrogen carbonate used instead of mixtures

- (d) Examiners were looking for three weighings and two masses of solid for at least one of the two additional tubes:

mass of tube; mass of tube + one solid; mass of tube + both solids; mass of sodium carbonate; mass of sodium hydrogen carbonate.

Use of a tare facility was permitted provided its use was stated.

Very few candidates recorded these weighings and masses. It was very common to weigh the two solids separately in tubes with identical recorded masses. The concern here would be whether the first solid was tipped out before the second solid was weighed. Many candidates, however, simply recorded the masses of the solids used.

Candidates were required to prepare the table of results in advance of the experiment. The mark available for this was not awarded where there was evidence, from rough jottings, of the experiment being performed first and the table then produced after the readings had been obtained.

See comments in (b) regarding units. The acceptable unit for mass is g. The use of gm, grm or gram are not acceptable as the symbol for the unit.

All weighings and the masses of the solid used should be recorded consistently to 1 decimal place or better.

There was a tendency for candidates to forfeit marks by careless recording of units and inconsistent decimal places in weighings. Candidates should appreciate that the final decimal place, even if zero, reflects the precision of the balance used.

- (e) The Examiners checked all subtractions in the Supervisor's results. The temperature changes for tubes **FB 5** and **FB 6** were scaled for 5.00 g of mixture if necessary. The Examiners then plotted the temperature changes for all five experiments on page 5 of the Supervisor's report and drew the best-fit line through the plotted points.

After checking all subtractions on the candidate scripts and calculating the percentage of sodium carbonate in each mixture, the temperature change for 5.00 g total of mixture (candidate results scaled if necessary) was compared to that obtained from the graph of the Supervisor's results.

Most candidates obtained a temperature change for at least one of the mixtures that was within 1 °C of the temperature change from the Supervisor's graph and gained "accuracy" marks. One of these marks was awarded where the smaller of the differences was between 1 °C and 2 °C.

- (f) The first mark was given for the use of appropriate scales, starting at -10 °C on the y-axis and covering 0% to 100% on the x-axis. A mark was available for accurate plotting of the five points on the graph.

Many candidates did not take sufficient care when placing the centre of a point on a graph. The Examiners were checking points to within half of a small square in either direction providing the point was within the “correct” square. Crosses drawn with blunt pencils or large “blobs” are not satisfactory points in this examination. If the centre of a point should be on a line of the graph paper, Examiners would like to see the centre of the plotted point on that line not to one side of it. Similarly points that are not on a line should not be plotted on a line. Points are checked to the nearest half of a small square but candidates should be able to work to a quarter of a small square or better.

Most candidates gained the mark for an appropriate straight line passing close to the points and intersecting the y-axis.

There was a mark available for “quality”. The Examiners considered their best-fit line through the plotted points and awarded the mark if no point was further than 0.5 °C from this line. Candidates who worked methodically, with consistent practical results, gained this mark.

**(g)** The Examiners were disappointed by the high proportion of candidates who could not read the intercept to within half of a small square on the y-axis scale.

**(h)** A very common error in **part (h)(i)** was to use 5.00 g of mixture in the **mcΔT** equation, rather than the 35 cm<sup>3</sup> of solution.

Common errors in **part (h)(ii)** were to:

- omit the +ve sign on the  $\Delta H$  value
- ignore the instruction to give the answer to 3 significant figures
- round  $\frac{5}{84}$  mol of sodium hydrogen carbonate from 0.0595 mol to 0.06 mol, use this rounded value in the calculation and obtain an answer that was not correct to 3 significant figures.

**(i)** The majority of candidates gave very poor answers to this part. Solid remaining in the tube and parallax errors were very common unacceptable answers.

Candidates had been instructed to ensure that all solid was transferred from the tube and parallax errors indicate a poor practical technique.

The Examiners were looking for one of the following:

- heat loss/gain with the surroundings
- acid spray from the vigorous reaction
- the use of a thermometer calibrated by 1 °C

The Examiners had hoped to see an explanation of how heat could be interchanged with the surroundings, e.g. convection or conduction, but this was seldom seen.

**(j)** This part was marked consequentially from a scoring point in **(i)**:

- suitable additional insulation or use of a lid
- use of a larger or deeper container
- use of a thermometer with closer graduation or use of a digital thermometer

**(k)** Most candidates gave answers related to what they had written in **(i)** and **(j)**, ignoring the instruction to refer to results. The Examiners were expecting comments on the quality of the straight line obtained in the experiment. Very few candidates referred to the graph they had drawn.

A small number of candidates who did refer to the graph commented that the experiment was unreliable as points were not on the line. The points they had plotted showed only minor deviation from the straight line drawn and they were, in fact, very good experimental points. Candidates should realise that experimental points are unlikely to lie exactly on the line of best fit.

**Question 2**

Candidates should appreciate that reagents are compounds (barium chloride or lead nitrate) and not just ions ( $\text{Ba}^{2+}$  or  $\text{Pb}^{2+}$ ) even when one of the ions present in the reagent is the “active” part of the reagent.

On this occasion, Examiners accepted named and appropriate aqueous ions or solutions containing those ions as reagents. Where incorrect formulae were given for a selected reagent but the intended reagent was clear to the Examiner, the identity of the reagent was allowed. In the conclusion **part (f)**, however, any formula for the ions or compound present and for the reagents used had to be correct to gain marks.

- (a) Many candidates selected barium chloride followed by hydrochloric acid as the pair of reagents but some candidates failed to specify which mineral acid was to be added. As this acid could have been sulphuric acid it negated the choice of the pair of reagents, although the observation mark was allowed from a white precipitate with barium chloride alone.

Other candidates chose barium chloride and lead nitrate added to separate samples of each solution.

- (b) Silver nitrate followed by aqueous ammonia, or silver nitrate and lead nitrate added to separate samples of each solution were acceptable pairs of reagents.

Most candidates obtained these marks.

- (c) Manganese(II) and magnesium cations were named. Candidates should therefore have been looking for one off-white precipitate and one white precipitate, both insoluble in excess sodium hydroxide.

Very few candidates reported any off-white precipitate – the precipitate with **FB 7** was often yellow, buff or light brown.

A mark for careful observation was included in this section, i.e. the off-white precipitate turning brown. This observation, or any darkening of the precipitate, was seldom recorded.

- (d) In this section the expected observations were the same as in (c). Another mark in this part was for recording a difference between the off-white precipitate with **FB 7** and the white precipitate with **FB 8**.

- (e) Only **FB 9** was acceptable for the solution containing more than one possible ion. Incorrect solubility in excess observations for **FB 8** and sodium hydroxide resulted in some candidates choosing aluminium and lead(II) as the possible cations. As **FB 8** should already have been identified as containing the sulphate ion, only manganese(II) or magnesium were acceptable cations.

Candidates who identified **FB 9** as the solution were able to choose two ions from  $\text{NH}_4^+$ ,  $\text{Ba}^{2+}$  or  $\text{Ca}^{2+}$ . (If a precipitate was formed between sodium hydroxide and **FB 9** only  $\text{Ba}^{2+}$  and  $\text{Ca}^{2+}$  were possible.)

A minority of candidates correctly identified the possible ions in **FB 9** but a significant number of these failed to say how they would identify the ion present – reagents were suggested but the expected results with these reagents and the ion under test were not explained.

A small number of candidates identified the ions possibly present in **FB 9**, described the test to be performed and its outcome and successfully carried out the test and came to a conclusion as to the ion present.

A significant number of candidates stated that ammonium salts on heating give ammonia gas although the necessary presence of sodium hydroxide was omitted.

- (f) Many candidates correctly identified the cations present but failed to give adequate supporting evidence and as a result gained no credit.

The minimum evidence for manganese(II) ions in **FB 7** was:

- an off-white precipitate with sodium hydroxide and with aqueous ammonia
- an off-white precipitate, insoluble in excess, with sodium hydroxide or with aqueous ammonia
- an off-white precipitate, turning brown, with sodium hydroxide or with aqueous ammonia

The minimum evidence for magnesium in **FB 8** was a white precipitate with sodium hydroxide and with aqueous ammonia. The Examiners did not insist on these precipitates being insoluble in excess reagent as magnesium was one of the ions given at the beginning of the question.

The evidence for the cation present in **FB 9** was consequential on the ions and reagents chosen in (e).

- (g) This part tested the candidates' powers of observation, and few candidates made all of the required observations:

- an off-white precipitate with sodium hydroxide
- the precipitate turning brown or black on addition of hydrogen peroxide solution
- no precipitate formed on adding hydrogen peroxide in the second test
- a brown or black precipitate formed on adding aqueous ammonia



# CHEMISTRY

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Paper 9701/04

A2 Structured Questions

## General comments

In general, Examiners were pleased with the overall performance of candidates in this session. Standards were once more variable, however, and somewhat Centre-dependent. Good Centres seem to be getting better, but some of the less good Centres had many candidates who struggled with the harder questions. There was very little evidence of candidates running out of time, which could be due to candidates having been better prepared for this longer paper.

There was the occasional example of a candidate losing marks by not reading the question carefully enough, but a greater concern this year was the lack of care and thought that often went into the extraction of the correct data from the *Data Booklet*.

The questions on the paper were intentionally graded according to difficulty, so that most candidates could make a good start on **Question 1**, whilst some of the later questions, and especially the latter parts of these, were designed to separate the very good from the good. Examples were **Questions 7, 8(c), 9(b) and 10(c)**. In general, however, Examiners were pleased to see that most candidates scored higher marks on the three Applications questions in **Section B** than they did last year, with average scores more than double last year's.

## Comments on specific questions

### **Section A**

#### **Question 1**

- (a) (i) This was well done by the majority of candidates. The commonest errors were to confuse the left-hand  $Cl_2/Cl^-$  electrode with the standard hydrogen electrode, and to suggest that the right-hand electrode was an  $Fe/Fe^{2+}$  electrode, rather than a  $Pt/Fe^{2+}, Fe^{3+}$  electrode. A bonus mark was available for including the standard conditions - gases at 1 atmosphere, solutions at  $1 \text{ mol dm}^{-3}$  and a temperature of 298K.
- (ii) Most candidates extracted the correct  $E^\ominus$  data, but several calculated the  $E^\ominus_{\text{cell}}$  as +0.59V, and predicted the wrong direction of electron flow (the correct answer was from right to left).
- (b) (i) Many candidates calculated the correct value here. Errors occurred through the use of incorrect multipliers, or mixing up the + and - signs for the various terms.
- (ii) The reaction expected was  $2Fe^{3+}(aq) + Cu(s) \rightarrow 2Fe^{2+}(aq) + Cu^{2+}(aq)$ . The molecular equation was also accepted. Various alternatives that were offered by candidates, such as  $\rightarrow Fe(s) + Cu^{2+}$  or  $\rightarrow Fe^{2+} + Cu^+$  were not allowed. The  $E^\ominus$  values extracted from the *Data Booklet* were sometimes not those related to the reaction stated by the candidate.

#### **Question 2**

- (a) (i) A large number of candidates calculated the correct value here. The usual errors occurred through the use of incorrect multipliers, or mixing up the + and - signs for the various terms. Common errors were to use the O-O single bond energy of  $150 \text{ kJ mol}^{-1}$  rather than the O=O bond energy of  $496 \text{ kJ mol}^{-1}$ ; not to multiply the O=O bond by two, or the C=O bond by four; or even to multiply incorrectly the C-Cl bond by two.

(ii) This question proved to be an excellent discriminator. Candidates who looked superficially at the  $\text{ClO}_2$  molecule, stated that it would be linear, like  $\text{CO}_2$ . Those who worked out the electron count around chlorine realised that there are three non-bonded electrons (one lone pair and an unpaired electron), and so were able to predict a bent V-shape for the molecule.

(iii) A surprisingly large number of candidates did not produce the balanced equation here:



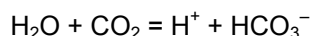
(b) (i) Accepted sources included coal-fired power stations; the burning of fossil fuels in cars; the contact process. The burning of (vulcanised) tyres, cement manufacture and the smelting of sulphide metal ores were other alternatives. Volcanoes were not accepted, since they do not arise from human activity.

(ii) Acid rain was the expected answer, with the consequences of lower pH of lakes or the leaching of aluminium from soils or the killing of fish and/or rainforests or the dissolving of limestone buildings.

(c) (i) Candidates often either failed to mention that  $\text{CO}_2$  was **both** covalent **and** simple molecular, or claimed that it was the weak covalent bonds in  $\text{CO}_2$  that were responsible for its low boiling point, rather than the weak van der Waals attractions between the molecules. An even more common error was to describe the bonding in  $\text{SnO}_2$  as metallic, rather than ionic.

(ii) Most candidates correctly described  $\text{SnO}_2$  as being the more stable to heat, but quite a number missed the “ $\frac{1}{2}$ ” from the equation  $\text{PbO}_2 \rightarrow \text{PbO} + \frac{1}{2}\text{O}_2$ .

(iii) Several candidates failed to read the stem of this part of the question, and had products other than the hydrogen carbonate ion and  $\text{H}^+$  on the right-hand sides of their equations. The expression for the equilibrium constant was awarded full marks consequentially, however, even if their equilibrium was incorrect. The accepted answer was as follows:



$$K_c = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{O}][\text{CO}_2]} \text{ or } = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{CO}_2]}$$

(iv) Although many candidates were able to write a correct equation for the reaction in which the  $\text{HCO}_3^-$  ion “mops up”  $\text{H}^+$  [ $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$ ] far fewer were able to produce the reaction between  $\text{HCO}_3^-$  and  $\text{OH}^-$  [ $\text{HCO}_3^- + \text{OH}^- \rightarrow \text{H}_2\text{O} + \text{CO}_3^{2-}$ ].

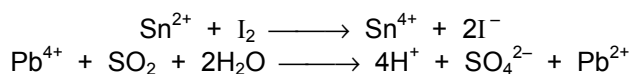
### Question 3

(a) Most candidates drew an acceptable tetrahedral diagram for  $\text{SiCl}_4$  (preferably with wedge and dotted bonds to represent the 3-dimensional nature of the molecule), although the inevitable incorrect square planar arrangement (with  $90^\circ$  angles) was also seen. However, far fewer candidates quoted the correct angle ( $109^\circ - 110^\circ$ ).  $120^\circ$  and  $104^\circ$  were very commonly quoted.

(b) Several candidates confused “volatility” with “reactivity”, and others seem to confuse it with “involatility”. The accepted reason for the decrease in volatility down the group was the increasing van der Waals force between the molecules due to the greater number of electrons in the  $\text{MCl}_4$  molecule.

(c) (i) Candidates were expected to quote the  $E^\ominus$  values for  $\text{Pb}^{4+}/\text{Pb}^{2+}$  at +1.69V and  $\text{Sn}^{4+}/\text{Sn}^{2+}$  at +0.15V, and to use these to state that the stability of the  $\text{M}^{4+}$  state relative to the  $\text{M}^{2+}$  state decreases down the group.

(ii) The correct equations were as follows:



Quite a number of candidates attempted to react  $\text{I}_2$  with  $\text{Sn}^{4+}$ , or wrote the equations for the reverse reactions. For the  $\text{Pb}^{2+}/\text{Pb}^{4+}$  mixture, some attempted to reduce  $\text{Pb}^{2+}$  to  $\text{Pb}(\text{s})$ , a reaction not predicted by the respective  $E^\ominus$  values ( $E_{\text{cell}}$  for  $\text{Pb}^{2+} + \text{SO}_2 = -0.30\text{V}$ , a negative quantity)

- (d)(i) A surprisingly large number of candidates failed to calculate the correct value here. The usual errors occurred through the use of incorrect multipliers, or mixing up the + and – signs for the various terms.
- (ii) Candidates were expected to relate the decreasing exothermicity of the  $MC_l_2 \rightarrow MC_l_4$  reaction down the group to the decreasing stability of the +4 state. This part was marked consequentially on the candidate's answers in (d)(i), i.e. if the candidate had calculated that the  $\Delta H$  value for Sn was *more* exothermic than that for Si, a mark could have been gained in (d)(ii) for stating (with a reason) that the results did *not* agree with (c)(i).

#### Question 4

- (a) The majority of candidates failed to score this easy mark for “ester”. Common errors were “carboxyl”, “carbonyl”, and even “alcohol”.
- (b) Although candidates were much better at recognising the reactants and conditions needed for these two reactions, they often lost a mark or two by offering incomplete answers. Thus for reaction I, the acid used had to be *dilute* or *aqueous* (alkali was also accepted as an alternative reagent), and the mixture had to be *heated*. For the esterification reaction II, methanol (a common error was to suggest ethanol) had to be heated with *concentrated* sulphuric acid.
- (c)(i) The tribromo compound  $BrCH_2CHBrCH_2Br$  was identified by many, although several candidates lost the mark by not being careful enough with their valencies:  $CH_2CH_2BrCH_2Br$  was a common wrong structure.
- (ii) Many candidates correctly oxidised the central secondary alcohol to a ketone, but only oxidised the two primary alcohol groups to aldehydes. Many others added a carbon atom, and either suggested  $HO_2C-C(OH)(CO_2H)-CO_2H$  or produced a trivalent carbon, ending up with  $HO_2C-C(CO_2H)-CO_2H$ . Another common wrong formula was  $HO_2C-C(O)(OH)-CO_2H$ , with a 5-valent central carbon.
- (d) Many candidates scored well here, although some forgot the factor of  $\times 3$ , or the factor of  $\times \frac{1}{2}$ , ending up with 167 kg or 1005 kg respectively. Partial credit was given, however.
- (e)(i) Common errors here were forgetting that the biodiesel already contained two oxygen atoms (thus  $57/2 O_2$  was used instead of  $55/2 O_2$ ) or producing 17  $CO_2$  or 18  $CO_2$  rather than the correct 19  $CO_2$ .
- (ii) This part was marked consequentially on the equation written in **part (e)(i)**. Most candidates scored well here.
- (f) A surprisingly large minority of candidates did not seem to know that fossil fuels are a depleting non-renewable resource. Other acceptable answers were comments about the net effect of bio fuels on the  $[CO_2]$  in the atmosphere being much less than that of fossil fuels, and the increasing price of fossil fuels.

#### Question 5

- (a) Although a good proportion of candidates scored two marks here, a significant number still confused *nucleophilic* and *electrophilic*.
- (b) Candidates often drew the intermediate cations with partial charges rather than full charges. In the case of ethene, either the open chain bromoethyl cation (with the + charge on carbon) or the 3-membered ring bromonium ion (with the + charge on bromine) was accepted. The Wheland intermediate in the benzene case had to have its + charge shown to be well away from the  $sp^3$  carbon - either associated with the delocalised “horseshoe” or, if a classical structure had been drawn, on the 2- or 4- position of the ring. For the conversion of the intermediate into the product, in the ethene case the curly arrow should have been drawn from the – charge (or better, a lone pair) on the  $Br^-$  ion to the  $C^+$ , and in the benzene case from the C–H bond into the delocalised horseshoe. Many candidates lost marks here through incomplete or carelessly drawn diagrams.

- (c) Many candidates scored well, here, for mentioning that the *delocalised* electrons in benzene conferred *stability* to the structure (and so the re-forming of the delocalised ring by proton loss in the second step is preferred over the addition of  $\text{Br}^-$ .)

### Question 6

This question combined the recall of knowledge about the reactions of aromatic compounds with the application of the information given in the question concerning the orientation of electrophilic substitution. A significant proportion of candidates seemed to ignore the information given in the question, and produced compounds oriented in somewhat random ways. The reactions of alkyl benzenes with  $\text{KMnO}_4$ , and of nitro compounds with  $\text{Sn} + \text{HCl}$ , were not as well-known as the nitration and bromination reactions.

Compound **A** is 4-bromomethylbenzene; compound **B** is 4-bromobenzoic acid; compound **C** is benzoic acid; compound **D** is 3-nitrobenzoic acid; and compound **E** is 3-aminobenzoic acid.

### Question 7

This question proved to be a good discriminator. Although most candidates could recognise whether the polymers had been formed by addition or condensation polymerisation, identifying the monomers proved increasingly difficult, with only the very good candidates drawing the correct structures of all seven. For the first polymer, the monomers were  $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$  and either  $\text{HO}_2\text{C}-\text{CO}_2\text{H}$  or  $\text{ClCO}-\text{COCl}$ . The second polymer was a condensation co-polymer of  $\text{HOCH}_2\text{CH}(\text{C}_2\text{H}_5)\text{CO}_2\text{H}$  and  $\text{HOCH}_2\text{CH}(\text{CH}_3)\text{CO}_2\text{H}$ , and the third was an addition co-polymer of  $\text{CH}_2=\text{CH}-\text{CH}_3$ ,  $\text{CH}_2=\text{CH}-\text{CONH}_2$  and  $\text{CH}_2=\text{CH}-\text{C}_6\text{H}_5$ .

## SECTION B Applications of Chemistry

It was clear to the Examiners that some Centres are still not preparing their candidates well for this section of the paper. However, it was also encouraging to find that, on average, many more candidates were able to make a reasonable attempt at all three Applications questions than was the case last year.

### Question 8

- (a) This question was designed to allow candidates to describe the similarities and differences between the types of bonding in the three types of structure. Thus the primary structure consists only of *covalent bonds* in the peptide groups; the secondary structure consists only of *hydrogen bonds* between the NH of one peptide group and the C=O of another one; whereas the tertiary structure can be held in place by either *van der Waals attractions* between hydrophobic groups, or *hydrogen bonds*, or *ionic attractions* between charged groups, or *covalent* disulphide bonds. Few candidates mentioned that the essential feature of the peptide bond (in this context) was its covalent nature, and quite a number of candidates added bonding types other than covalent and hydrogen to their descriptions of primary and secondary structures. Diagrams, i.e. part structural formulae, were usually fairly well drawn, although some hydrogen bonds within the secondary structure were not clearly from the peptide  $\text{NH}-\text{O}=\text{C}$  groups, and some hydrogen bonds within the tertiary structure **were** (incorrectly) shown as  $\text{NH}-\text{O}=\text{C}$  groups. The disulphide bonds were often shown as  $-\text{S}-\text{S}-$  or  $-\text{S}=\text{S}-$  (or even  $-\text{SH}-\text{SH}-$ ) rather than the correct single bonded  $-\text{S}-\text{S}-$ .
- (b) The smallest polypeptide that fitted the data is the octapeptide met-ala-gly-ala-gly-arg-val-lys, and a small number of candidates worked this out correctly. Most merely joined the six tripeptides together in a correct order, with *met* at the left hand end and *lys* at the right.
- (c) Quite a number of candidates confused the interchanging of two amino acids with the interchanging of two bases in DNA. Many also thought that this question was concerned with either sickle cell anaemia or cystic fibrosis. In fact, answers that referred to these two conditions often missed the point of the question, which was how the protein shape and folding would change due to the disruption of the side-chain interactions within the tertiary structure. Candidates were therefore expected to describe that the disruption, and the re-forming in a different place along the chain, of hydrogen bonds and ionic or van der Waals interactions (or disulphide bridges), could alter the shape and solubility of the protein, and could also affect its activity as an enzyme. The mark scheme was quite wide-ranging, and marks were also obtainable for identifying the side chain groups on amino acids involved (e.g. serine, lysine, glutamate, cysteine, valine, etc.), although this was not essential.

## Question 9

- (a) This part was answered well. Most candidates knew that the charge on, and the molar mass of, the amino acid were factors, as were its shape/size and also the strength of the electric field. Some candidates lost a mark by describing the *mass of the amino acid* (in grams) rather than its **molar** mass or the mass of one molecule. The pH of the buffer was not accepted as an answer, since the question stated that the solution was of a *given pH*. Concentration also has no effect.
- (b) This part was extremely poorly answered. Many candidates seemed to have little idea of what information can be gained from either NMR or mass spectra, and even less of the origins of the peaks. A considerable number seemed to confuse the two – answers in (i) referring to fragmentation and in (ii) referring to the splitting of peaks and chemical shifts. Clearly, this is a part of the Applications section that would benefit from more intensive teaching and learning.
- (i) Candidates were expected to be aware that the NMR spectrum of propanone would contain just one singlet peak (at about  $\delta$  2.1) because all six hydrogen atoms are in the same chemical environment. The NMR spectrum of propanal, however, would contain three peaks, the CH<sub>3</sub> being split into a triplet, the CHO either as a singlet or a triplet (depending on the magnitude of its splitting by the CH<sub>2</sub> group), and the CH<sub>2</sub> as a quartet or quintet. However, full marks were obtainable without quoting splittings or  $\delta$  values, by merely stating that there would be three sets of peaks for propanal because there are three different proton environments.
- (ii) It was important for candidates to identify fragments that would be likely to be different for the two compounds. Propanone is likely to have a simpler mass spectrum than propanal, being a symmetrical molecule. Peaks at  $m/e$  15 (CH<sub>3</sub>) and 43 (CH<sub>3</sub>CO) are most likely. Propanal, on the other hand, will have a strong peak at  $m/e$  29 due to the formation of both C<sub>2</sub>H<sub>5</sub> and CHO, as well as (lesser) peaks at  $m/e$  15, 43 and 57.
- (c) (i) Candidates were expected to identify peaks at  $m/e$  79 **and** 81, or 94 **and** 96, due to the isotopes of bromine. Only the more able scored these marks.
- (ii) Candidates were expected to know that the M:M+2 ratio for chlorine is 3:1 (not 1:3 as quite a number stated), whereas the ratio for bromine is 1:1. Candidates often stated that “the M:M+2 ratios would be different” without stating their values. Several candidates also quoted 9:6:1 and 1:2:1 ratios, assuming that the molecule contained **two** halogen atoms.

## Question 10

- (a) Most candidates were able to score at least one mark here. Reasons accepted included the following:
- to speed delivery (of drug to target organ)
  - to avoid the drug being hydrolysed/reacted/decomposed in the stomach
  - to allow a smaller dose to be used *or* greater accuracy of dosage
  - patient does not have to be conscious
- (b) (i) Most candidates failed to score a mark for this part. Examiners were looking for a description of a nanosphere as being a sphere with a diameter of the order of a few nanometres. Many candidates merely re-stated the questions and stated that a nanosphere was a nanosized particle, without saying what “nanosized” meant.
- (ii) Most candidates correctly stated that the stomach contains a strong acid, hydrochloric acid.
- (iii) Most candidates scored at least one mark. Any two of the following were accepted for full marks:
- use hydrogels of different wall thickness/strength (to release drug over time)
  - use hydrogels of different chemical composition (for different breakdown times)
  - incorporate holes or pores into the hydrogel walls

- (c) There was a large variety of possible correct answers here. Although a “repeat unit” was not asked for, the portion of polymer drawn had to convince the Examiners that the chain could be continued without recourse to anhydride or ether linkages. Thus for the homopolymer, a polyamide from the amino acid was acceptable, as was the polyester from the hydroxydiacid. (The former was the most popular.) For the heteropolymer, all three monomers could have been used, to form alternating ester and amide bonds (this turned out to be the most popular heteropolymer amongst the candidates), or a polyester could be made using the diol and the hydroxydiacid. Forming an ester linkage between the diol and the amino acid, however, turned out to be a dead end: there is no way the  $\text{-OH}$  on one end could be joined to the  $\text{-NH}_2$  on the other end. Forming another ester bond between the other  $\text{-OH}$  of the diol and another molecule of amino acid produces a molecule with an  $\text{-NH}_2$  group at *both* ends.

# CHEMISTRY

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Paper 9701/05

Planning, analysis and evaluation

## General comments

Overall, the paper proved to be quite challenging with some of the part questions only occasionally producing a correct response. Nevertheless, correct responses to all the questions were seen. Very high marks were extremely rare while a few candidates failed to achieve any marks at all. Candidates often failed to appreciate the precision of answer required by some of the questions, and there was evidence of unfamiliarity with some of the concepts involved. Greater familiarity with experimental techniques would be of benefit to all candidates.

## Comments on specific questions

### *Section A*

#### Question 1

- (a) Although many candidates correctly identified  $\text{CH}_2$  as being the correct difference, responses referring to carbon alone, or indeed to the methyl group, were not uncommon.
- (b) The linearly increasing negativity of the enthalpy of combustion with increasing number of carbon atoms was generally understood and correctly represented, although there were some curved graphs and lines with a positive slope.
- (c) Candidates encountered difficulties in all parts of this question. There was considerable confusion over the dependent/independent variable relationship, with a wide variety of suggestions, and further problems over the choice of variables to be controlled. Common errors were references to temperature rather than temperature change, and the volume or concentration of the alcohol rather than the mass or number of moles.
- (d) Of the six required points, the precision element was only infrequently dealt with correctly, and more often was omitted. In most cases, the dependent variable was identified correctly as the temperature change but, although the ethanol was usually mentioned as the independent variable, the mass was not always seen as the correct measure. The volume of the ethanol was a frequent erroneous suggestion as indeed were a variety of ethanolic solutions. Some candidates placed the ethanol instead of water in the beaker. The points dealing with the processing of the experimental results proved to be much more difficult. Again, the volume of the ethanol was often incorrectly used to determine the number of moles of ethanol, while the integrity of the units was frequently flawed.
- (e) There was some confusion here as to the difference between the measurements taken and the subsequent deductive calculations. Ideally there should be initial and final temperatures and initial and final weighings of the spirit lamp. The table should allow for results for all the alcohols and each measurement should have the correct units. Just recording the temperature change and the mass were frequently seen answers.
- (f) Ideally, to successfully answer this section candidates need to be fully conversant with the laboratory techniques involved in exercises such as this as well as the likely sources of measurement errors. The improvements looked for were basically in two categories, reducing heat loss from the copper can and attempting to ensure that as much as possible of the heat from the spirit lamp reaches the can. In addition, candidates needed to indicate which particular aspect of the heat loss would be corrected by the improvement. The statement that a particular improvement would reduce the loss of heat to the atmosphere merely repeated a part of the question. Enclosing

the complete apparatus inside a form of heat shield was a common error as was the exchange of the copper can for either a glass beaker or a plastic cup. Many candidates found this section very difficult.

### Question 2

- (a) There were very few arithmetic errors in completing the table, although not all the values were recorded to two decimal places. Errors occurred when the column headings were either incomplete or incorrect, a particular one being the incorrect naming of the mass loss. This was often labelled as either loss of water or loss of carbon dioxide, rather than the loss of both.
- (b) The graph plotting was generally carried out successfully with many candidates extending the graph correctly through the origin. However, not all the points were accurately plotted and although this was not penalised in this section, there were possible consequences in subsequent sections.
- (c) This section proved to be difficult for most candidates. Too many merely copied down co-ordinates directly from the table and sometimes these were on the line itself. The appropriate anomalous point, (student 3), was frequently incorrectly plotted, and those who merely took the co-ordinates from the table failed to access the first mark. The point was anomalous due to loss of solid during the heating, but very few were able to identify this reason.
- (d) Again, to be able to answer this section a correct graph was needed with the two highest points not lying on the line. The correct answer was that, for these higher masses, the decomposition was incomplete. Those for whom these two points were on the line found difficulty here.
- (e) The mark here was consequential to (d) and was accessed by most candidates.
- (f) The most difficult section of **Question 2**. Appropriate lines had to be drawn on the graph, with the derived values being then recorded with units. While the construction lines were often correctly drawn, the derived values were often incorrectly read from the graph, and units were frequently omitted. The calculation varied in difficulty dependent on the two variables plotted, with the most advantageous being that of original mass against residual mass. Some candidates seemed to have had difficulty reconciling the emergent value of  $x$  as around 0.5.
- (g) Despite having drawn a fully correct graph, some candidates did not realise that this was supportive of an appropriate procedure.
- (h) The required answer here needed to be quite precise. Statements such as 'measure the amount of gas evolved' were inappropriate, as was 'measure the volume of water'. A measure of the volume of carbon dioxide was acceptable, as was a measure of the mass of water produced, the latter either by condensation or by absorption by a suitable substance.
- (i) Generally well answered with most candidates appreciating the decreasing percentage error.