

# CHEMISTRY

Paper 9701/11  
Multiple Choice

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

This examination paper provided a challenge to the candidates. There were some good performances, but no outstanding ones. However, the entry for this paper was very low with only twenty candidates. The mean mark was 15/40, the median mark was 14/40, and there were three modal marks, 12, 13 and 14. Given the low entry it is important not to read too much into these numbers, or into those that follow.

Eleven questions can be said to have been found to be easier. These were **Questions 2, 7, 10, 12, 13, 14, 19, 21, 26, 29** and **39**. Six questions can be said to have been found to be particularly difficult. These were **Questions 1, 9, 16, 25, 34** and **36**.

The questions that were found to be particularly difficult will now be looked at in greater detail.

**Question 1:** The correct answer was B. The most commonly chosen incorrect answer was A. This suggests that the majority knew that the melting and boiling points of X means that it is a liquid, hence Br<sub>2</sub>, but did not appreciate that the density of Y means that it floats on water. Y is therefore Na not Al.

**Question 9:** The correct answer was D. The most commonly chosen incorrect answer was C. The answer C arises from the sum  $0.56^2/0.44^2$ . However, silver is a solid as is shown by the state symbol in the

question, therefore it should not be included when calculating  $K_c$ . The correct answer D arises from the sum  $0.56/0.44^2$ .

**Question 16:** The correct answer was B. The most commonly chosen incorrect answers were A and D. The answer is B because if the cell is stirred two of the products react:  $\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaCl} + \text{NaOCl}$ . This was detailed in the question – “. . . in a cell which is stirred so that products of electrolysis react with each other.”

**Question 25:** The correct answer was C. The most commonly chosen incorrect answer was B. Answer B arises if candidates calculate 75% of 2.76 g. However, the product of the reaction will have been ethanoic acid. Starting with 2.76 g (0.06 mol) of ethanol, 100% yield would have been 3.60 g (0.06 mol) of ethanoic acid, therefore a 75% yield is 2.70 g.

**Question 34:** The correct answer was A. The most commonly chosen incorrect answer was B. Candidates who chose B had decided that statement 3 was false. However all soils contain  $\text{CO}_2$  in the air spaces.  $\text{Ca}(\text{OH})_2$  is basic while  $\text{CO}_2$  is acidic, therefore the reaction in statement 3 will occur.

**Question 36:** The correct answer was A. The statistics suggest that a significant proportion of candidates guessed their response. Questions in this subject area require knowledge of the pollutant oxides  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$  and  $\text{SO}_3$ . The question says oxide Y can be oxidised, so Y must be  $\text{CO}$ ,  $\text{NO}$ , or  $\text{SO}_2$ . The question says this oxidation is spontaneous in the atmosphere, so Y must be  $\text{NO}$ . Therefore, Z must be  $\text{NO}_2$  and X must be N. Statements 1, 2, and 3 are therefore all true, and the answer is A.

# CHEMISTRY

Paper 9701/12  
Multiple Choice

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

This examination paper provided a challenge to many of the candidates. However there were many good performances, as well as some outstanding ones. Three candidates scored full marks.

Ten questions can be said to have been found to be easier. These were **Questions 1, 5, 8, 12, 16, 19, 21, 22, 28** and **32**. Five questions can be said to have been found to be particularly difficult. These were **Questions 10, 26, 29, 37** and **40**.

The questions that were found to be particularly difficult will now be looked at in greater detail.

**Question 10:** The correct answer was A. The most commonly chosen incorrect answers were C and D. One approach to this question would have been to draw a "Hess's Law cycle" with  $\text{C(g)} + 4\text{H(g)} \rightarrow \text{CH}_4\text{(g)}$  as the unknown energy change. The value of this energy change is four times the average C–H bond energy in methane. If the third corner of the cycle is  $\text{C(s)} + 2\text{H}_2\text{(g)}$  then the data needed is the standard enthalpy change of atomisation of carbon, the standard enthalpy change of atomisation of hydrogen, and the standard enthalpy change of formation of methane.

**Question 26:** The correct answer was A. The most commonly chosen incorrect answer was B. Answer B arises if candidates calculate 70% of 2.30 g. However, the product of the reaction will have been ethanal. Starting with 2.30 g (0.05 mol) of ethanol, 100% yield would have been 2.20 g (0.06 mol) of ethanal, therefore a 70% yield is 1.54 g.

**Question 29:** The correct answer was D. The most commonly chosen incorrect answers were A and B. This suggests that many candidates did not appreciate the significance of the second reaction in the question, which shows that X must be methylpropene.

**Question 37:** The correct answer was D. The most commonly chosen incorrect answers was C. It is possible that these candidates had not carefully read the question. Statement 1 is the only set of results that could **not** be obtained, as compound X, whose formula is  $C_4H_{10}O$ , cannot be an aldehyde. The candidates who chose C may have done so because they realised that statements 2 and 3 give sets of results that could be obtained from isomers of  $C_4H_{10}O$ , having not spotted the wording of the question.

**Question 40:** The correct answer was A. Similar numbers of candidates chose each answer. This suggests that it is possible that a significant number of candidates guessed their answer. This question is not inherently difficult, although the general formulae of the homologous series mentioned do have to be applied in an unusual way. The answer therefore has to be worked out and would not just be known.

**\*Question 30:** This question contained some ambiguity. As a result, in this exceptional circumstance, answers A and B were both credited.

# CHEMISTRY

Paper 9701/13  
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There were many good performances, as well as some outstanding ones. Two candidates scored full marks.

Twelve questions can be said to have been found to be easier. These were **Questions 4, 6, 8, 9, 11, 13, 19, 23, 24, 26, 29** and **40**. **Questions 38, 39** and **40** were all answered correctly by a good proportion of the candidates, suggesting that most candidates found they had sufficient time to complete the paper properly.

Five questions can be said to have been found to be particularly difficult. These were **Questions 5, 12, 17, 35** and **36**.

The questions that were found to be particularly difficult will now be looked at in greater detail.

**Question 5:** The correct answer was C. The most commonly chosen incorrect answers were A and B. Answers A and B possibly arose from the assumption that the bond angle at nitrogen is always close to  $109.5^\circ$ . Candidates who chose C possibly drew a 'dot-and-cross' diagram, or considered the nitrogen atom to be "analogous" to a carbon atom in ethene.

**Question 12:** The correct answer was D. The most commonly chosen incorrect answer was C. The answer C arises from the sum  $0.56^2/0.44^2$ . However, silver is a solid as is shown by the state symbol in the question, therefore it should not be included when calculating  $K_c$ . The correct answer D arises from the sum  $0.56/0.44^2$ .

**Question 17:** The correct answer was B. The most commonly chosen incorrect answers were A and D. The answer is B because if the cell is stirred two of the products react:  $\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaCl} + \text{NaOCl}$ . This was detailed in the question – “. . . in a cell which is stirred so that products of electrolysis react with each other.”

**Question 35:** The correct answer was A. The most commonly chosen incorrect answers were B and D. Candidates who chose B or D had decided that statement 3 was false. However all soils contain  $\text{CO}_2$  in the air spaces.  $\text{Ca}(\text{OH})_2$  is basic while  $\text{CO}_2$  is acidic, therefore the reaction in statement 3 will occur. The question does **not** ask “which reactions occur as a consequence of adding both lime and ammonium nitrate to the soil”, although it seems possible that many candidates have answered it in this way. It was hoped that, since the statements 1, 2 and 3 all involve  $\text{Ca}(\text{OH})_2$  and not  $\text{CaO}$ , candidates would consider the possible roles of other constituents already in the soil.

**Question 36:** The correct answer was A. The most commonly chosen incorrect answer was C. Answers A, B and D were equally popular. Questions in this subject area require knowledge of the pollutant oxides  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$  and  $\text{SO}_3$ . The question says oxide Y can be oxidised, so Y must be  $\text{CO}$ ,  $\text{NO}$ , or  $\text{SO}_2$ . The question says this oxidation is spontaneous in the atmosphere, so Y must be  $\text{NO}$ . Therefore, Z must be  $\text{NO}_2$  and X must be N. Statements 1, 2, and 3 are therefore all true, and the answer is A.

# CHEMISTRY

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<p>Paper 9701/21 AS Structured Questions</p>
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## Key Messages

- Candidates should read each question carefully before answering in order to decide exactly what that particular question requires.
- Candidates are reminded that numerical answers should be given to an appropriate number of significant figures. Answers should reflect the number of significant figures given in the question.

Some questions specify that answers should be given to a particular number of significant figures or decimal places. In such cases, candidates should ensure that their answers meet the stated requirements.

- Candidates are also reminded that it is important that Examiners can read their answers without difficulty. Credit cannot be obtained where answers are not legible.

## General Comments

The paper tested candidates' knowledge of inorganic and organic chemistry and their understanding of chemical principles.

There were many excellent answers to each of the individual questions.

## Comments on Specific Questions

### Question 1

The ability to use the mole concept to determine an empirical formula is an important skill. There were many correct answers to the calculations of mass in the first three parts of this question but fewer candidates correctly calculated the corresponding numbers of moles. This usually led to problems in deducing the empirical formula in **(b)**. When this was correctly calculated, the remainder of the question was usually completed correctly.

- (a)** In this section, candidates were instructed to give their answers to three decimal places.
- (i)** The majority of candidates correctly showed that the mass of carbon present in 0.352 g of CO<sub>2</sub> was 0.096 g. Fewer were able to divide this mass by the  $A_r$  of carbon and convert it into 0.008 mol of carbon present in 0.240 g of **A**.
- (ii)** There were many correct answers of 0.016 g of hydrogen present in 0.144 g of H<sub>2</sub>O in this part. This means that 0.016 mol of hydrogen atoms were present in 0.240 g of **A**.

However, a significant number of those candidates who gave a correct answer for the mass of hydrogen then used the  $M_r$  of hydrogen (2) rather than its  $A_r$  (1) and gave an incorrect answer.

- (iii)** This part produced fewer fully correct answers with many candidates not realising how to calculate the required mass which is given by the following equation;

$$\text{mass of oxygen present in 0.240 g of A} = 0.240 - (0.096 + 0.016) = 0.128 \text{ g}$$

As with the number of moles of hydrogen atoms, some candidates divided this mass by the  $M_r$  of oxygen (32) rather than by the  $A_r$  (16). Using the latter gives the number of moles of oxygen atoms as 0.008 present in 0.240 g of **A**.

- (b) Many candidates correctly used their answers to (a) to show that the empirical formula of **A** was  $\text{CH}_2\text{O}$ . Those candidates who were able to use their wrong values from (a) to produce a possible empirical formula such as  $\text{CHO}$  were given credit. However, candidates who gave answers such as  $\text{C}_{60}\text{H}_{10}\text{O}$  should have considered whether their 'compound' was a possibility and then gone back to check their original calculation.
- (c)
- (i) The majority of candidates used the equation  $pV = nRT$  correctly to give  $M_r = 59.9$ . Common mistakes involved incorrectly converting  $\text{kPa}$  to  $\text{Nm}^{-2}$  and/or  $\text{cm}^3$  to  $\text{m}^3$ . A very small number of candidates used  $^\circ\text{C}$  rather than  $\text{K}$ .
- (ii) Using the answers to (b) and (c)(i) gives the molecular formula of **A** as  $\text{C}_2\text{H}_4\text{O}_2$ .
- (d) Many candidates correctly identified  $\text{CH}_3\text{CO}_2\text{H}$  as one isomer of **A**. Fewer gave  $\text{HCO}_2\text{CH}_3$  as the other. In spite of the information given in the question, a number of candidates gave structures which were alkenes or carbonyl compounds.
- (e) This was well answered by the majority of candidates.

## Question 2

The study of first ionisation energies has helped in our understanding of the electronic configuration of atoms. There were many good explanations in (b) and (c) and many candidates demonstrated good knowledge in (d).

- (a) While there were many correct answers, a common wrong answer involved the formation of the anions  $\text{S}^-$  or  $\text{S}^{2-}$ . Some candidates did not give state symbols as requested. In a number of cases, Examiners were unable to decide whether the state symbol given was (s) or (g). In such cases credit was not awarded.
- (b) Many candidates correctly explained the change in terms of increasing nuclear charge, atomic radius and shielding of outer electrons. A common wrong explanation involved the increasing numbers of electrons from Na to Ar.
- (c) The best answers gave the electronic configuration of each of the four elements concerned. Most of these candidates were then able to explain very clearly the differences in ionisation energy between each pair of elements. Examiners recommend this as a way of beginning such answers.
- (i) This was poorly answered by some candidates who did not state clearly why the outer electron of aluminium can be removed more easily than that of magnesium.
- (ii) There were many ambiguous answers to this part in terms of 'filled', 'partially filled' or 'half-filled' orbitals. Those candidates who gave the electronic configurations, or who stated clearly that in the sulfur atom, one 3p orbital has a pair of electrons in it, avoided that ambiguity. In the latter case a statement to the effect that electron pairs repel usually led to further credit being awarded.
- (d) Most candidates gave three or four correct answers in this part. The most common wrong answer was to state that sodium has a high melting point.
- (e) This part produced many correct answers of 'silicon'. The most common wrong answer was 'gallium' which, by analogy with aluminium chloride would not have a low boiling point chloride.

## Question 3

Those candidates who understood how to use the equation, energy change =  $mc\Delta T$  and were able to apply Hess' Law performed well on this question. There were, however, many candidates who struggled with the calculations. Some candidates gave incorrect signs for endo- and exothermic reactions, Centres are reminded that the syllabus, in **section 5(a)**, states that for exothermic reactions,  $\Delta H$  is negative.



- (a) Most candidates gave a correct definition of Hess' Law.
- (b)
- (i) The majority of candidates gave a correct equation.
  - (ii) Although there were many correct answers to this part, a significant number of candidates did not carry out the calculation correctly. The most common problem was to use an incorrect mass in the equation given above, with candidates calculating the actual mass of  $K_2CO_3$  which is much less than the mass of water used in the experiment. As Examiners often find, some candidates added 273 to the change in temperature, while a small number used a wrong value for the specific heat capacity of water. In many of the answers to this part, the units were incorrectly given as  $J g^{-1}$  or  $J mol^{-1}$  or  $kJ mol^{-1}$ .
  - (iii) In this part, candidates had to express their answers in  $kJmol^{-1}$  and include a sign with their answer.
  - (iv) This was well answered by the majority of candidates.
- (c)
- (i) Again, the majority of candidates gave a correct equation.
  - (ii) As with (b)(ii) there were many incorrect answers in which candidates had not used the data correctly. There were also many different units offered.
  - (iii) Once again, many candidates did not use the correct units or omitted the sign.
- (d) While there was a good number of correct answers, many candidates clearly did not know how to apply Hess' Law correctly.

#### Question 4

This question tested candidates' knowledge of some straightforward organic chemistry. It was generally well answered, particularly by those candidates who had revised their organic chemistry thoroughly.

- (a) The majority of candidates gave correct structures for compounds **T**, **U**, and **V**. The most common mistakes occurred in the oxidation of **V** to **W** where candidates did not oxidise the primary alcohol or the secondary alcohol in **V** correctly.
- (b) This was less well done. The most common error was to produce a propyl ester of butanoic acid rather than a butyl ester of propanoic acid.

#### Question 5

The last question on the paper required candidates to apply their knowledge and understanding to an unusual molecule. Although there were fewer correct answers to this question, the stronger candidates gave some good answers.

- (a)
- (i) Most candidates correctly identified the two functional groups present. Despite the requirement to name them 'as fully as you can' few stated that the alcohol was a 'primary alcohol'. A small number gave 'carbonyl' instead of 'aldehyde' which Examiners did not accept because this name includes ketones.
  - (ii) There were many correct answers to both parts with good descriptions of what would be seen in each case. A common wrong answer was the use of acidified potassium dichromate(VI) which Examiners did not accept because it will react with both functional groups.
- (b) The drawing of skeletal formulae is still causing problems to many candidates.

- (c) A number of candidates struggled with this part but there were some good answers from candidates who applied their knowledge carefully.
- (i) In answering this question candidates had to be aware of the possible effects of their chosen reagents on both of the functional groups present in  $\text{HOCH}_2\text{CHO}$ . At some stage an oxidation to form the  $-\text{CO}_2\text{H}$  group must take place and it would be easier to do this after the  $-\text{NH}_2$  group is present. Candidates made two common errors; they converted the alcohol group directly into an amine using ammonia, which cannot be done or they reduced the aldehyde group to an alcohol and subsequently oxidised it to the carboxylic acid. While this is perfectly feasible, it is much easier to oxidise the aldehyde directly to carboxylic acid.
- (ii) Those candidates who gave a correct pair of intermediates were usually able to state appropriate reagents to bring about the desired changes.

# CHEMISTRY

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Paper 9701/22

AS Structured Questions

## Key Messages

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Some questions specify that answers should be given to a particular number of significant figures or decimal places. In such cases, candidates should ensure that their answers meet the stated requirements.

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## General Comments

The paper tested candidates' knowledge of inorganic and organic chemistry and their understanding of chemical principles.

There were many excellent answers to each of the individual questions.

## Comments on Specific Questions

### Question 1

The ability to use the mole concept to determine an empirical formula is an important skill. There were many correct answers to the calculations of mass in the first three parts of this question but fewer candidates correctly calculated the corresponding numbers of moles. This usually led to problems in deducing the empirical formula in **(b)**. When this was correctly calculated, the remainder of the question was usually completed correctly.

- (a)** In this section, candidates were instructed to give their answers to three decimal places.
- (i)** The majority of candidates correctly showed that the mass of carbon present in 0.352 g of CO<sub>2</sub> was 0.096 g. Fewer were able to divide this mass by the  $A_r$  of carbon and convert it into 0.008 mol of carbon present in 0.240 g of **A**.
- (ii)** There were many correct answers of 0.016 g of hydrogen present in 0.144 g of H<sub>2</sub>O in this part. This means that 0.016 mol of hydrogen atoms were present in 0.240 g of **A**.

However, a significant number of those candidates who gave a correct answer for the mass of hydrogen then used the  $M_r$  of hydrogen (2) rather than its  $A_r$  (1) and gave an incorrect answer.

- (iii)** This part produced fewer fully correct answers with many candidates not realising how to calculate the required mass which is given by the following equation;

$$\text{mass of oxygen present in 0.240 g of A} = 0.240 - (0.096 + 0.016) = 0.128 \text{ g}$$

As with the number of moles of hydrogen atoms, some candidates divided this mass by the  $M_r$  of oxygen (32) rather than by the  $A_r$  (16). Using the latter gives the number of moles of oxygen atoms as 0.008 present in 0.240 g of **A**.

- (b) Many candidates correctly used their answers to (a) to show that the empirical formula of **A** was  $\text{CH}_2\text{O}$ . Those candidates who were able to use their wrong values from (a) to produce a possible empirical formula such as  $\text{CHO}$  were given credit. However, candidates who gave answers such as  $\text{C}_{60}\text{H}_{10}\text{O}$  should have considered whether their 'compound' was a possibility and then gone back to check their original calculation.
- (c)
- (i) The majority of candidates used the equation  $pV = nRT$  correctly to give  $M_r = 59.9$ . Common mistakes involved incorrectly converting  $\text{kPa}$  to  $\text{Nm}^{-2}$  and/or  $\text{cm}^3$  to  $\text{m}^3$ . A very small number of candidates used  $^\circ\text{C}$  rather than  $\text{K}$ .
- (ii) Using the answers to (b) and (c)(i) gives the molecular formula of **A** as  $\text{C}_2\text{H}_4\text{O}_2$ .
- (d) Many candidates correctly identified  $\text{CH}_3\text{CO}_2\text{H}$  as one isomer of **A**. Fewer gave  $\text{HCO}_2\text{CH}_3$  as the other. In spite of the information given in the question, a number of candidates gave structures which were alkenes or carbonyl compounds.
- (e) This was well answered by the majority of candidates.

## Question 2

The study of first ionisation energies has helped in our understanding of the electronic configuration of atoms. There were many good explanations in (b) and (c) and many candidates demonstrated good knowledge in (d).

- (a) While there were many correct answers, a common wrong answer involved the formation of the anions  $\text{S}^-$  or  $\text{S}^{2-}$ . Some candidates did not give state symbols as requested. In a number of cases, Examiners were unable to decide whether the state symbol given was (s) or (g). In such cases credit was not awarded.
- (b) Many candidates correctly explained the change in terms of increasing nuclear charge, atomic radius and shielding of outer electrons. A common wrong explanation involved the increasing numbers of electrons from  $\text{Na}$  to  $\text{Ar}$ .
- (c) The best answers gave the electronic configuration of each of the four elements concerned. Most of these candidates were then able to explain very clearly the differences in ionisation energy between each pair of elements. Examiners recommend this as a way of beginning such answers.
- (i) This was poorly answered by some candidates who did not state clearly why the outer electron of aluminium can be removed more easily than that of magnesium.
- (ii) There were many ambiguous answers to this part in terms of 'filled', 'partially filled' or 'half-filled' orbitals. Those candidates who gave the electronic configurations, or who stated clearly that in the sulfur atom, one 3p orbital has a pair of electrons in it, avoided that ambiguity. In the latter case a statement to the effect that electron pairs repel usually led to further credit being awarded.
- (d) Most candidates gave three or four correct answers in this part. The most common wrong answer was to state that sodium has a high melting point.
- (e) This part produced many correct answers of 'silicon'. The most common wrong answer was 'gallium' which, by analogy with aluminium chloride would not have a low boiling point chloride.

## Question 3

Those candidates who understood how to use the equation, energy change =  $mc\Delta T$  and were able to apply Hess' Law performed well on this question. There were, however, many candidates who struggled with the calculations. Some candidates gave incorrect signs for endo- and exothermic reactions, Centres are reminded that the syllabus, in **section 5(a)**, states that for exothermic reactions,  $\Delta H$  is negative.

- (a) Most candidates gave a correct definition of Hess' Law.
- (b)
- (i) The majority of candidates gave a correct equation.
  - (ii) Although there were many correct answers to this part, a significant number of candidates did not carry out the calculation correctly. The most common problem was to use an incorrect mass in the equation given above, with candidates calculating the actual mass of  $K_2CO_3$  which is much less than the mass of water used in the experiment. As Examiners often find, some candidates added 273 to the change in temperature, while a small number used a wrong value for the specific heat capacity of water. In many of the answers to this part, the units were incorrectly given as  $J g^{-1}$  or  $J mol^{-1}$  or  $kJ mol^{-1}$ .
  - (iii) In this part, candidates had to express their answers in  $kJ mol^{-1}$  and include a sign with their answer.
  - (iv) This was well answered by the majority of candidates.
- (c)
- (i) Again, the majority of candidates gave a correct equation.
  - (ii) As with (b)(ii) there were many incorrect answers in which candidates had not used the data correctly. There were also many different units offered.
  - (iii) Once again, many candidates did not use the correct units or omitted the sign.
- (d) While there was a good number of correct answers, many candidates clearly did not know how to apply Hess' Law correctly.

#### Question 4

This question tested candidates' knowledge of some straightforward organic chemistry. It was generally well answered, particularly by those candidates who had revised their organic chemistry thoroughly.

- (a) The majority of candidates gave correct structures for compounds **T**, **U**, and **V**. The most common mistakes occurred in the oxidation of **V** to **W** where candidates did not oxidise the primary alcohol or the secondary alcohol in **V** correctly.
- (b) This was less well done. The most common error was to produce a propyl ester of butanoic acid rather than a butyl ester of propanoic acid.

#### Question 5

The last question on the paper required candidates to apply their knowledge and understanding to an unusual molecule. Although there were fewer correct answers to this question, the stronger candidates gave some good answers.

- (a)
- (i) Most candidates correctly identified the two functional groups present. Despite the requirement to name them 'as fully as you can' few stated that the alcohol was a 'primary alcohol'. A small number gave 'carbonyl' instead of 'aldehyde' which Examiners did not accept because this name includes ketones.
  - (ii) There were many correct answers to both parts with good descriptions of what would be seen in each case. A common wrong answer was the use of acidified potassium dichromate(VI) which Examiners did not accept because it will react with both functional groups.
- (b) The drawing of skeletal formulae is still causing problems to many candidates.

- (c) A number of candidates struggled with this part but there were some good answers from candidates who applied their knowledge carefully.
- (i) In answering this question candidates had to be aware of the possible effects of their chosen reagents on both of the functional groups present in  $\text{HOCH}_2\text{CHO}$ . At some stage an oxidation to form the  $-\text{CO}_2\text{H}$  group must take place and it would be easier to do this after the  $-\text{NH}_2$  group is present. Candidates made two common errors; they converted the alcohol group directly into an amine using ammonia, which cannot be done or they reduced the aldehyde group to an alcohol and subsequently oxidised it to the carboxylic acid. While this is perfectly feasible, it is much easier to oxidise the aldehyde directly to carboxylic acid.
- (ii) Those candidates who gave a correct pair of intermediates were usually able to state appropriate reagents to bring about the desired changes.

# CHEMISTRY

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Paper 9701/23  
AS Structured Questions

## Key Messages

- Candidates should read each question carefully before answering in order to decide exactly what that particular question requires.
- Candidates are reminded that numerical answers should be given to an appropriate number of significant figures. Answers should reflect the number of significant figures given in the question.

Some questions specify that answers should be given to a particular number of significant figures or decimal places. In such cases, candidates should ensure that their answers meet the stated requirements.

- Candidates are also reminded that it is important that Examiners can read their answers without difficulty. Credit cannot be obtained where answers are not legible.

## General Comments

There were many excellent answers to each of the individual questions. The majority of candidates performed well on **Question 1**, while many coped well with the calculations in **Question 2**. The stronger candidates provided good answers in **Question 3** giving sound explanations in (b) and (c). **Question 4** involved much factual recall and indicated which candidates had concentrated on this aspect of their revision. **Question 5** involved some organic problem solving which provided good answers from the more able candidates.

## Comments on Specific Questions

### Question 1

This question tested candidates' knowledge and understanding of isotopes. There were many very good answers to this question, demonstrating a sound understanding of the topic.

- (a) Most candidates offered a correct definition. A small minority mentioned compounds or molecules instead of isotopes.
- (b) Most candidates performed the calculation correctly giving the answer as 32.09. Some candidates did not give their answer to two decimal places as instructed.
- (c) Most candidates were awarded full credit here.
- (d)
  - (i) Most candidates used the information given to deduce the correct answers. Some candidates confused nucleons and neutrons.
  - (ii) Many candidates correctly used the Periodic Table in the *Data Booklet* to identify element *E* as radium.

## Question 2

The ability to carry out routine calculations involving moles and reacting masses is an important skill tested in this question.

- (a)
- (i) The majority of candidates calculated the mass of carbon. Fewer were able to calculate the amount of moles of carbon atoms in 0.42 g of **A**.
  - (ii) Many candidates calculated the mass of hydrogen present. As with (i), fewer were able to calculate the amount of moles. A common mistake was to confuse hydrogen atoms and hydrogen molecules.
  - (iii) Correct numerical answers gave the empirical formula as  $\text{CH}_2$  so **A** was an alkene.
- (b)
- (i) The majority of candidates did this standard calculation correctly showing that the empirical formula of **B** was  $\text{C}_4\text{H}_{10}\text{O}$ .
  - (ii) Most candidates realised **B** was butan-2-ol and drew displayed formulae of the mirror object/mirror image correctly. Candidates who did not indicate the chiral carbon atom or did not draw carefully the 3-dimensional structure with hashed and wedged bonds did not receive full credit.
  - (iii) Common errors here were to include butan-2-ol or to offer the same compound twice.

## Question 3

The study of first ionisation energies has helped in our understanding of the electronic configuration of atoms. Many candidates coped well with some aspects of this question.

- (a) Some candidates did not give state symbols as instructed. In some cases, answers were not legible and Examiners were unable to determine whether the state symbol given was (s) or (g).
- (b)
- (i) Most candidates knew or deduced that magnesium had the greater nuclear charge but many did not mention that both atoms lose 3s electrons in order to form the cation.
  - (ii) Candidates had to appreciate that the aluminium electron removed was from a 3p orbital and the magnesium electron from a 3s orbital, with the 3p electron being further from the nucleus. Not all were able to do this.
  - (iii) Only the very able candidates realised that He and Ne had the highest nuclear charges in their period.
  - (iv) Many candidates repeated the question saying the first ionisation energy decreased down the group. Able candidates made the three salient points that down the group the atomic size increases, causing greater shielding, with the result that the attraction between valence electrons and the nucleus is less.
- (c)
- (i) It was realised by the majority of candidates that the important fact was the increase in nuclear charge from Na to Cl.
  - (ii) Most candidates mentioned the cation had fewer electrons than the corresponding atom. However, few candidates added that the nuclear charge of the cation and the corresponding atom were the same.
- (d) Many candidates incorrectly gave reactions for the first and sixth equations, clearly not appreciating that basic oxides do not react with alkalis and acidic oxides do not react with acids. The second and fourth equations were generally well answered. However, the third equation proved demanding with few candidates knowing the identity of the product; Examiners accepted  $\text{NaAl}(\text{OH})_4$  or  $\text{Na}_3\text{Al}(\text{OH})_6$ . The fifth equation often had  $\text{Na}_2\text{SO}_4$  as a product rather than  $\text{Na}_2\text{SO}_3$  or  $\text{NaHSO}_3$ .



#### Question 4

Much of the organic chemistry at AS Level has to be learned by candidates and it was clear to Examiners that a number of candidates who took this paper did not have good knowledge of all of the reactions involved. There were also many candidates who did not understand how to draw a skeletal formula.

- (a)
- (i) Many candidates gave the molecular formula  $C_4H_{10}O_2$  rather than the empirical formula  $C_2H_5O$ .
  - (ii) Candidates still struggle with drawing skeletal formulae. Common errors were to show four rather than five carbon atoms or to include C symbols in the formula.
- (b)
- (i) Most candidates realised that **S** and **U** were structural isomers or functional group isomers.
  - (ii) The compounds expected were **P** (*cis*- and *trans*-isomers) and **T** (optical isomers).
- (c)
- (i) Candidates generally recognised that this was a dehydration or elimination reaction.
  - (ii) Candidates then usually gave concentrated  $H_2SO_4$  as the reagent. Some candidates omitted the word 'concentrated' or gave 'alcoholic NaOH' for the elimination.
  - (iii) Candidates who answered (i) and (ii) correctly scored well here.
- (d)
- (i) Many candidates deduced the product was  $CH_2=CHCH=CH_2$ . As the reagent was in an excess,  $HOCH_2CH_2CH=CH_2$  was incorrect.
  - (ii) Stronger candidates recalled the reaction needed steam and a phosphoric acid catalyst.
  - (iii) Most candidates realised oxidation was needed and used acidified potassium dichromate(VI). The most common error was to omit the presence of the acid.

#### Question 5

The last question on the paper required candidates to apply their knowledge and understanding to three different compounds with the same empirical formula. As with **Question 4**, many candidates struggled with parts of this question.

- (a) Many candidates correctly gave HCHO or  $H_2CO$ . Unacceptable formulae were HCOH and  $CH_2O$ .
- (b)
- (i) Most candidates realised **W** was an ester. Those who gave an answer of  $-COO-$  or  $-CO_2-$  were penalised because this formula could represent a carboxylic acid.
  - (ii) Many candidates correctly deduced **W** as  $HCO_2CH_3$ .
- (c)
- (i) The more able candidates realised **X** was  $HOCH_2CH_2CO_2H$ . The acid  $CH_3CH(OH)CO_2H$  was incorrect because its oxidation product would react with 2,4-dinitrophenylhydrazine.
  - (ii) Candidates who gave the correct answer in (i) usually gave the correct answer of  $HO_2CCH_2CO_2H$  in this part. Some credit was given for  $CH_3COCO_2H$  if candidates had given  $CH_3CHOHCO_2H$  for **X** in (i).
- (d)
- (i) Only the more able candidates deduced the formula of the cyclic ester, **Z**.
  - (ii) Candidates often recognised this reaction as esterification or condensation even if their formula for **Z** was incorrect.

# CHEMISTRY

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<p><b>Paper 9701/31</b> <b>Advanced Practical Skills 1</b></p>
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## Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Systematic errors are the ones normally to be considered and not human errors as the latter should not arise.

## General comments

The Examiners thank Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** for each session/laboratory. Centres are reminded that the Examiners expect to see in the script packet for each session and for each laboratory within a session the following documentation:

- a list of the candidates present and a seating plan for the laboratory,
- a copy of the examination paper with the Supervisor's experimental results.

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 to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, all Centres running more than one session, and/or using more than one laboratory, should instruct their candidates to complete the session/laboratory boxes on the front of the examination paper.

Examiners take steps to obtain the missing data through Cambridge Assessment but it is often unobtainable and candidates may be disadvantaged as a consequence.

It is important that Centres check reactants and reagents prior to the examination as if one is time-expired and does not work it disadvantages the candidates. It is also important that the apparatus specified in the Confidential Instructions is supplied for the examination as there were indications from some Centres that thermometers graduated at 0.2 °C may have been used to the disadvantage of the candidates.

Almost all the candidates completed the paper in the allocated time although a few weaker candidates appeared to rush or omit either parts of the calculations in **Question 1** or some of the observations in **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

## Comments on Specific Questions

### **Question 1**

The majority of the candidates were able to complete the practical work successfully in the question, and most were able to gain at least partial credit in the calculation. The majority also gained at least partial credit for the graph work though more care was needed by many in drawing lines of best fit. Graphs in Chemistry papers are generally straight lines or smooth curves.

- (a) Almost all candidates completed the seven experiments and were able to calculate the rise in temperature correctly. However, there were a few candidates who read the thermometer incorrectly (2.00 °C instead of 20.0 °C) and many more who did not record the thermometer

readings to the expected level of precision. Thermometers calibrated to 1 °C should be read to the nearest .0 °C or .5 °C and without interpolation to inappropriate decimal places. At least one of the quoted readings should show this degree of accuracy in reading by a temperature ending in .5 °C (rather than all being to .0 °C). A significant minority of candidates did not achieve the expected constant temperature rise in the latter experiments. Many candidates are likely to have carried out a thermometric titration which produces a drop in temperature after the end point is reached and it appeared that some candidates changed correct readings to fit their expectations. Generally the award of credit for accuracy tended to be Centre dependent although there were good results from individual candidates where others from the Centre had performed poorly. However, the majority of candidates gained at least partial credit for accuracy.

- (b) A large majority of candidates chose scales so that at least half the available squares were used and plotted all points correctly. However, some chose difficult scales so that plotting and then reading the intercept was difficult for both candidate and Examiner. A few did not label the axes or did not record units in any of the forms specified in the syllabus. Many candidates did not receive credit for the two best fit intersecting straight lines. A number of candidates left more points to the one side of the line than the other. The use of (0,0) may have assisted some candidates to improve the line for the increase in temperature rise. If candidates realise that one of their results is anomalous they should circle or otherwise indicate this decision on the graph so that the point is not considered by Examiners when awarding credit for best fit lines.
- (c) The most common error in this section was that candidates did not show they had read the intercept to the nearest half square as many answers were given as whole numbers. Some candidates were unable to gain credit as the intercept was less than the maximum temperature rise recorded. However, there were many candidates who correctly gave the values of  $\Delta T$  and volume to the level of precision shown in the graph.
- (d) Relatively few candidates gained full credit as the responses tended to describe the shape of the graph or the temperature rise without relating it to any reaction between the acid and alkali. Many candidates identified that excess alkali was being added and received credit for this. A small minority of candidates wrote about bond breaking and making without specifying that more water was formed in successive experiments (until all the limiting reagent had reacted). Very few answered the question incorrectly in terms of equilibria or kinetics.
- (e) The most common error in this section was using a volume other than 65 cm<sup>3</sup> in the calculation. However, the majority of candidates were able to gain credit for the calculation although some gave the answer to an excessive number of significant figures.
- (f) This section was correctly answered by most candidates.
- (g) Most candidates were able to gain partial credit. However, some gave an inappropriate number of significant figures, no conversion of J to kJ, or, more commonly, writing  $\Delta H$  or + for the sign.
- (h) The majority of candidates did not appear to understand this question and answered in terms of fair testing, keeping the concentration constant or other responses commonly associated with kinetics experiments. However, there were a few excellent answers where the candidates clearly linked temperature rise to energy produced.
- (i) Many gained full credit in this section though a significant number did not specify the mole ratio of the reactants which was an essential part of their working.
- (j) Only a minority of candidates gained credit here. The majority suggested increasing volumes of reagents, increasing the concentration of just one of the reagents, or gave methods of reducing heat energy losses.
- (k) The majority gained partial credit in this section though a variety of responses were seen by Examiners including a few curves. A smaller number gained further credit for a correct temperature scale or for the intercept being at the same values as those in (b).

## Question 2

The standard of answers in this question tended to be Centre dependent. There were some excellent answers where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout; very few confused 'cation' and 'anion'. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. It was apparent that most candidates recognised the need to use the Qualitative Analysis Notes and the advisability of using the precise terminology included in these. Candidates should be reminded that any reagent chosen for use must be given its full name or correct formula.

### (a)

- (i) Most candidates selected a suitable reagent with the majority choosing to use a named mineral acid.
- (ii) A large majority set out an appropriate table for their observations and were able to access at least partial credit for observations. It is important that candidates appreciate the difference between an observation, e.g. 'effervescence' and an inference, e.g. 'gas is evolved'. Not all of those using acid as their reagent went on to test the gas(es) produced which meant that there was insufficient evidence for the identification of the anions. However, the most discerning candidates reported the difference in the rate of effervescence when using acid with **FA 3** and **FA 4**.

### (b)

- (i) The majority of candidates were able to gain at least partial credit in this section; this was most commonly awarded for the two white precipitates in the first two steps and the white precipitate soluble in excess aqueous sodium hydroxide. However, there are still candidates who report 'white solution' or 'cloudy white' instead of 'white precipitate'. The heating section was not as familiar to candidates and many possible observations were omitted. Credit most commonly awarded was for the brown gas though some were able to identify  $\text{NO}_2$  and/or  $\text{O}_2$  from a correct test with a positive result. Very few candidates received credit for noting the solid turning yellow or for the sound made by the solid as it was heated.
- (ii)  $\text{Pb}^{2+}$  was the cation most commonly identified though a few candidates did not have sufficient correct observations for this conclusion.
- (iii) A large majority of candidates selected a suitable reagent though a small number did not give its full name or formula so were unable to be awarded credit. Most candidates reported the correct observation for  $\text{Pb}^{2+}$  with their chosen reagent and received credit for this.

# CHEMISTRY

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<p><b>Paper 9701/33</b> <b>Advanced Practical Skills 1</b></p>
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## Key Messages

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readings to the expected level of precision. Thermometers calibrated to 1 °C should be read to the nearest .0 °C or .5 °C and without interpolation to inappropriate decimal places. At least one of the quoted readings should show this degree of accuracy in reading by a temperature ending in .5 °C (rather than all being to .0 °C). A significant minority of candidates did not achieve the expected constant temperature rise in the latter experiments. Many candidates are likely to have carried out a thermometric titration which produces a drop in temperature after the end point is reached and it appeared that some candidates changed correct readings to fit their expectations. Generally the award of credit for accuracy tended to be Centre dependent although there were good results from individual candidates where others from the Centre had performed poorly. However, the majority of candidates gained at least partial credit for accuracy.

- (b) A large majority of candidates chose scales so that at least half the available squares were used and plotted all points correctly. However, some chose difficult scales so that plotting and then reading the intercept was difficult for both candidate and Examiner. A few did not label the axes or did not record units in any of the forms specified in the syllabus. Many candidates did not receive credit for the two best fit intersecting straight lines. A number of candidates left more points to the one side of the line than the other. The use of (0,0) may have assisted some candidates to improve the line for the increase in temperature rise. If candidates realise that one of their results is anomalous they should circle or otherwise indicate this decision on the graph so that the point is not considered by Examiners when awarding credit for best fit lines.
- (c) The most common error in this section was that candidates did not show they had read the intercept to the nearest half square as many answers were given as whole numbers. Some candidates were unable to gain credit as the intercept was less than the maximum temperature rise recorded. However, there were many candidates who correctly gave the values of  $\Delta T$  and volume to the level of precision shown in the graph.
- (d) Relatively few candidates gained full credit as the responses tended to describe the shape of the graph or the temperature rise without relating it to any reaction between the acid and alkali. Many candidates identified that excess alkali was being added and received credit for this. A small minority of candidates wrote about bond breaking and making without specifying that more water was formed in successive experiments (until all the limiting reagent had reacted). Very few answered the question incorrectly in terms of equilibria or kinetics.
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- (f) This section was correctly answered by most candidates.
- (g) Most candidates were able to gain partial credit. However, some gave an inappropriate number of significant figures, no conversion of J to kJ, or, more commonly, writing  $\Delta H$  or + for the sign.
- (h) The majority of candidates did not appear to understand this question and answered in terms of fair testing, keeping the concentration constant or other responses commonly associated with kinetics experiments. However, there were a few excellent answers where the candidates clearly linked temperature rise to energy produced.
- (i) Many gained full credit in this section though a significant number did not specify the mole ratio of the reactants which was an essential part of their working.
- (j) Only a minority of candidates gained credit here. The majority suggested increasing volumes of reagents, increasing the concentration of just one of the reagents, or gave methods of reducing heat energy losses.
- (k) The majority gained partial credit in this section though a variety of responses were seen by Examiners including a few curves. A smaller number gained further credit for a correct temperature scale or for the intercept being at the same values as those in (b).

## Question 2

The standard of answers in this question tended to be Centre dependent. There were some excellent answers where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout; very few confused 'cation' and 'anion'. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. It was apparent that most candidates recognised the need to use the Qualitative Analysis Notes and the advisability of using the precise terminology included in these. Candidates should be reminded that any reagent chosen for use must be given its full name or correct formula.

### (a)

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- (ii)  $\text{Pb}^{2+}$  was the cation most commonly identified though a few candidates did not have sufficient correct observations for this conclusion.
- (iii) A large majority of candidates selected a suitable reagent though a small number did not give its full name or formula so were unable to be awarded credit. Most candidates reported the correct observation for  $\text{Pb}^{2+}$  with their chosen reagent and received credit for this.

# CHEMISTRY

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<p><b>Paper 9701/34</b> <b>Advanced Practical Skills 2</b></p>
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## Key Messages

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### **Question 1**

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- (a) Almost all candidates completed the seven experiments and were able to calculate the rise in temperature correctly. However, there were a few candidates who read the thermometer



incorrectly (2.00 °C instead of 20.0 °C) and many more who did not record the thermometer readings to the expected level of precision. Thermometers calibrated at 1 °C should be read to the nearest .0 °C or .5 °C and without interpolation to inappropriate decimal places. At least one of the quoted readings should show this degree of accuracy in reading by a temperature ending in .5 °C (rather than all being to .0 °C). Generally the award of credit for accuracy tended to be Centre dependent although there were good results from individual candidates where others from the Centre had performed poorly.

- (b) A majority of candidates chose scales so that at least half the available squares were used, and plotted all points correctly. However, some chose difficult scales so that plotting and then reading the intercept was difficult for both candidate and Examiner. Others did not include the data from the final two columns as instructed. Only a few did not label the axes or did not record units in any of the forms specified in the syllabus. Many candidates did not receive credit for the two best fit intersecting straight lines. A few candidates used only two points to draw a straight line and a larger number left more points to one side of the line than the other. The use of (0,0) may have assisted some candidates to improve the line for the increase in temperature rise. If candidates decide that one of their results is anomalous, and there is insufficient time to repeat the set of readings, they should circle or otherwise indicate this decision on the graph so that the point is not considered by Examiners when awarding credit for best fit lines.
- (c)
- (i) The most common error in this section was that candidates did not show they had read the intercept to the nearest half square as many answers were given as whole numbers.
  - (ii) Some candidates were unable to gain credit as the intercept was less than the maximum temperature rise recorded. However, there were many candidates who correctly gave the values of  $\Delta T$  and volume to the level of precision shown in the graph.
  - (iii) This part was answered well by almost all candidates.
  - (iv) The most common error in this section was using a volume other than 50 cm<sup>3</sup> in the calculation. However, the majority of candidates were able to gain credit for the calculation although some gave the answer to an excessive number of significant figures.
  - (v) Most candidates gained credit for showing how to calculate  $\Delta H$  for one mole. However, some could not be awarded further credit owing to an inappropriate number of significant figures, no conversion of J to kJ, or, more commonly, writing  $\Delta H$  or + for the sign.
- (d) The response to this tended to be Centre dependent with a significant number of candidates incorrectly identifying parallax error as an error in the experimental method. It is an error the experimenter should not be making and so could not be awarded credit. The most common correct response focused on the greater (percentage) error of the measuring cylinder used for **FB 2** compared with a burette.
- (e)
- (i) Not all candidates referred to the total volume used in each experiment and so used an incorrect volume of acid in the calculation.
  - (ii) Although the majority of candidates recognised the 2:1 mole ratio of hydrogen ions in H<sub>2</sub>SO<sub>4</sub> compared with HCl, it was common to see the answer from (i) multiplied instead of divided by 2.
  - (iii) Some candidates did not appreciate that the required test was for a sulfate ion and others incorrectly selected Pb(NO<sub>3</sub>)<sub>2</sub> or the incomplete reagent, Ba<sup>2+</sup>. Most noted the white precipitate formed.

## Question 2

The standard of answers in this question tended to be lower than for the first question. The less familiar tests in (b) caused problems for weaker candidates. However, there were some excellent answers where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout, e.g. very few confused 'cation' and 'anion'. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. It was apparent

that most candidates recognised the need to use the Qualitative Analysis Notes and the advisability of using the precise terminology included in these. Candidates should be reminded that any reagent chosen for use must be given its full name or correct formula.

(a)

- (i) A large majority set out an appropriate table for their observations. It is important that candidates appreciate the difference between an observation, e.g. 'effervescence' and an inference, e.g. 'gas is evolved'. Many candidates omitted testing the gas produced. Most candidates were able to identify chromate though slightly fewer identified carbonate. The most common error in this section was to identify more than one anion for each of **FB 3** and **FB 4**.
- (ii) The majority of candidates correctly selected silver nitrate as the reagent, with or without aqueous ammonia. However, some incorrectly selected  $\text{Pb}(\text{NO}_3)_2$  even though it had already been used in (i), or the incomplete reagent,  $\text{Ag}^+$ . A significant minority did not observe a cream precipitate and so were unable to identify  $\text{Br}^-$ .

(b)

- (i) Most correctly observed effervescence but few tested the gas and of those who did there were a number incorrectly reporting limewater turning milky or the gas popping with a lighted splint. Candidates should be reminded that there is frequently a noise as a glowing splint reignites when oxygen is present and that this does not signify hydrogen.
- (ii) Few candidates obtained the expected colour of filtrate although most reported a red-brown or brown precipitate after the addition of  $\text{NaOH}$ .
- (iii) Most candidates were able to correctly observe a green filtrate. Relatively few candidates obtained a pink or purple solution after adding acid to the green filtrate.

Only the most able candidates gave the expected conclusions from their observations. The identification of  $\text{O}_2$  was seen as often as an appreciation that **FB 6** was acting as a catalyst. More candidates gained credit for the second part of the conclusion but some appeared confused in stating that **FB 6** contained the  $\text{Fe}^{3+}$  ion rather than oxidising the  $\text{FeSO}_4$  reagent used.

# CHEMISTRY

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<p>Paper 9701/35 Advanced Practical Skills 1</p>
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## Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Systematic errors are the ones normally to be considered and not human errors as the latter should not arise.

## General Comments

The Examiners thank Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** for each session/laboratory. Centres are reminded that the Examiners expect to see in the script packet for each session and for each laboratory within a session the following documentation;

- a list of the candidates present and a seating plan for the laboratory,
- a copy of the examination paper with the Supervisor's experimental results.

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 to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, all Centres running more than one session, and/or using more than one laboratory, should instruct their candidates to complete the session/laboratory boxes on the front of the examination paper.

Examiners take steps to obtain the missing data through Cambridge Assessment but it is often unobtainable and candidates may be disadvantaged as a consequence.

It is important that Centres check reactants and reagents prior to the examination as if one is time-expired and does not work it disadvantages the candidates. It is also important that the apparatus specified in the Confidential Instructions is supplied for the examination as there were indications from some Centres that thermometers graduated at 0.2 °C may have been used to the disadvantage of the candidates.

Almost all the candidates completed the paper in the allocated time although a few weaker candidates appeared to rush or omit some of the observations in **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

## Comments on Specific Questions

### Question 1

The majority of the candidates were able to complete the practical work successfully in the question. The precision with which the answer is given is very important for the award of full credit; this was particularly apparent in **(h)**. The majority gained at least partial credit for the graph work though more care was needed by many in drawing lines of best fit. Graphs in Chemistry papers are, almost without exception, straight lines or smooth curves.

- (a)** The majority of candidates clearly stated the initial and final temperatures and the reaction times, and gave the correct units. The instruction to record the reaction time to the nearest second was not always followed. There were a number of candidates who did not record the thermometer

readings to the expected level of precision. Thermometers calibrated to 1 °C should be read to the nearest .0 °C or .5 °C and without interpolation to inappropriate decimal places. At least one of the quoted readings should show this degree of accuracy in reading by a temperature ending in .5 °C (rather than all being to .0 °C). Candidates should be encouraged to obtain at least 5 results when a graph has to be drawn, and that in this experiment the temperatures chosen should cover the whole range with no two readings being too close together.

- (b) Candidates generally calculated the mean temperatures and rates correctly with most realising that both should be quoted to an appropriate number of significant figures/decimal places.

Credit was awarded for how competently the candidate had carried out the practical exercise and this was judged by considering how each individual candidate's times varied with the temperatures they actually used.

- (c) A majority of candidates chose scales so that at least half the available squares were used, and plotted all points correctly. However, some chose difficult scales so that plotting was difficult for both candidate and Examiner. If candidates realise that one of their results is anomalous they should circle or otherwise indicate this decision on the graph so that the point is not considered by Examiners when awarding credit for lines (straight or curved) of best fit. The majority of candidates extrapolated the (curved) line to 20 °C, and credit for the rate at this temperature correctly read from the graph was awarded even when the value was highly unlikely.
- (d) Since the question stated that temperatures 10 °C apart should be considered, it was not acceptable to choose results that did not correspond to this temperature difference. Candidates should confirm or deny the statement that the rate would double as long as their statement followed from their results. Most candidates who correctly quoted rates went on to interpret the data correctly.
- (e) Most candidates recognised that the greatest percentage error was for the reaction with the smallest time. A few chose other reactions but were still able to gain credit for calculating the percentage error.
- (f)(g) A wide variety of errors and modifications were possible and most candidates correctly attempted an error based on the procedure used. Some responses were well thought through whilst weaker candidates often gave the almost standard response for an experiment involving taking thermometer readings of 'heat loss' with the modification of use lagging or a lid.
- (h) Most candidates were able to gain partial credit but only a few were awarded full credit. Most recognised that the volume of FA 1 should be altered but many did not state that the total volume should be kept constant.

## Question 2

The standard of answers in this question tended to be Centre dependent. However, there were some excellent answers where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. It was apparent that most candidates recognised the need to use the Qualitative Analysis Notes and the advisability of using the precise terminology included in these. Candidates should be reminded that any reagent chosen for use must be given its full name or correct formula.

- (a) Most candidates noted they should not use an indicator to identify the acid and a number of acceptable answers were seen. The most common answers were based on carbonate or chromate(VI). A significant minority of candidates suggested the use of an alkali and, although clearly this will react with an acid, the lack of a visible reaction with an acid meant that a temperature rise was needed for credit to be given.
- (b) The majority of candidates gained some credit in this part with only the difference in effect of excess hydrochloric acid really giving significant difficulties.
- (c) This is an example where precision of expression is necessary. To gain full credit it was necessary to state that it was a gas or that it was ammonia that turned the litmus blue. A number of candidates clearly observed the result of the test correctly but merely stated that the litmus went

blue. Without the inclusion of 'gas' or 'ammonia' this colour change could have been due to the sodium hydroxide solution.

- (d) Some well-reasoned answers were seen but, as stated above, credit will not be given if the ion suggested does not give the test results seen in earlier parts of the question. This applies even if the ion is actually correct.
- (e) The answer expected was the use of aqueous silver nitrate and the formation of a cream precipitate. Many candidates recognised the need for this test and that it is necessary to include the full name of the reagent and a precise description of the appearance of the product.

# CHEMISTRY

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Paper 9701/36

Advanced Practical Skills 2

## Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Systematic errors are the ones normally to be considered and not human errors as the latter should not arise.

## General Comments

The Examiners thank Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** for each session/laboratory. Centres are reminded that the Examiners expect to see in the script packet for each session and for each laboratory within a session the following documentation;

- a list of the candidates present and a seating plan for the laboratory,
- a copy of the examination paper with the Supervisor's experimental results.

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 to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, the Examiners would appreciate it if all Centres running more than one session, and/or using more than one laboratory, would instruct their candidates to complete the Session and Laboratory boxes on the front of the examination paper.

Examiners take steps to obtain the missing data through Cambridge Assessment but it is often unobtainable and candidates may be disadvantaged as a consequence.

It is important that Centres check reactants and reagents prior to the examination as if one is time-expired and does not work it disadvantages the candidates.

Almost all the candidates completed the paper in the allocated time although a few weaker candidates appeared to rush or omit some of the observations in **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

## Comments on Specific Questions

### **Question 1**

The majority of the candidates were able to complete the practical work successfully in the question. Candidates needed to apply their knowledge to solve problems in a less familiar context here. The majority gained at least partial credit for the graph work though more care was needed by many in drawing lines of best fit. Graphs in Chemistry papers are generally straight lines or smooth curves.

- (a) The majority of candidates recorded the volume of propanone, the volume of water and the reaction time clearly and usually in a table with headings and the relevant units. The instruction to record the reaction time to the nearest second was not always followed, with a significant number of times being given to one or two decimal places.

- (b) A large majority of candidates chose volumes of propanone and water so that the total volume remained  $20 \text{ cm}^3$ . For full credit it was necessary to spread the volumes used across the possible range so that no two readings were too close together.
- (c) The number of moles was generally correct and nearly all candidates showed how they calculated their answers.
- (d) Most candidates also correctly calculated the 'rate' using the expression given but only the most able gave the correct unit. This was commonly omitted or given as  $\text{s}^{-1}$ . Again, most candidates correctly quoted the rate to a minimum of 2 significant figures.
- (e) A majority of candidates chose scales so that at least half the available squares were used, and plotted all points correctly. However, some chose difficult scales so that plotting was difficult for both candidate and Examiner. If candidates realise that one of their results is anomalous they should circle or otherwise indicate this decision on the graph so that the point is not considered by Examiners when awarding credit for lines (straight or curved) of best fit. In this case a straight line plot was expected and many candidates recognised that it should pass through the origin.

The candidate's practical competence in carrying out the experiment was judged by how close their reaction times, using specified volumes of propanone, were to those recorded by the Supervisor for that Centre. A majority clearly handled the apparatus well and thus produced consistent results.

- (f)
- (i) Most candidates recognised that an increase in concentration of propanone led to an increase in rate with the most able putting this more precisely by noting that there was direct proportionality between the two.
- (ii) A precise answer that applied specifically to the situation under consideration was needed in this part. Weaker candidates tended merely to suggest some sort of repeat.
- (g) Whilst the majority of candidates recognised that, to halve the concentration of iodine,  $5 \text{ cm}^3$  should be used, only the most able realised that the volume of water must be increased by  $5 \text{ cm}^3$  to keep the total volume constant. A small number also realised that, in the calculation of 'rate', the initial concentration of iodine has to be halved.
- (h) Credit was given for any correct comparison between the rate calculated in (g) and the rate for the same volume of propanone in (b).
- (i) Since an individual burette reading is accurate to  $0.05 \text{ cm}^3$ , the error in the measurement of  $20.0 \text{ cm}^3$  is  $0.1 \text{ cm}^3$ . It was encouraging to note that more candidates realised this than had been observed in previous years. Most candidates were able to calculate the percentage error.

## Question 2

The standard of answers in this question tended to be Centre dependent. However, there were some excellent answers where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. It was apparent that most candidates recognised the need to use the Qualitative Analysis Notes and the advisability of using the precise terminology included in these. Candidates should be reminded that any reagent chosen for use must be given its full name or correct formula.

- (a) Most candidates noted they should not use an indicator to identify the acid and a number of acceptable answers were seen. The most common answers were based on carbonate or chromate(VI). A significant minority of candidates suggested the use of an alkali and, although clearly this will react with an acid, the lack of a visible reaction with an acid meant that a temperature rise was needed for credit to be given.
- (b) This is an example of where a precise answer was needed if full credit was to be gained. The formation of white precipitates in the first two tests and that of bubbling in the third were generally noted. The identification of the gas was described by only the most able since the answer must clearly show that it is the gas that is being tested with the limewater.

- (c) A large majority of candidates gave a suitable layout for their results with small volumes then excess of the two alkalis. The observations of the reactions with **FB 5** were usually correct. However, many candidates missed the reminder that a boiling tube should be used if warming an aqueous solution, and the note about testing for an ammonium ion on page 11. Of those who heated **FB 6** with aqueous sodium hydroxide only some made it clear that it was the gas that turned the litmus blue.
- (d) Some well-reasoned answers were seen but, as stated above, credit will not be given if the ion suggested does not give the test results seen in earlier parts of the question. This applies even if the ion suggested is actually the one present.



# CHEMISTRY

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Paper 9701/41  
A2 Structured Questions

## Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

## General Comments

There were a number of excellent answers to this paper. The paper discriminated well, and it was felt that it was successful in rewarding those who had a good knowledge and understanding of the subject.

Most candidates generally wrote legibly, although there were still instances of them not reading the questions carefully enough. For example, in **Question 1(d)** some candidates drew molecular rather than structural or skeletal formulae and in **Question 6(a)(ii)** once again skeletal formulae were often not given.

Examiners found no evidence that candidates had run out of time.

This report should be read in conjunction with the published mark scheme for this paper.

## Comments on Specific Questions

### Section A

#### Question 1

(a)

- (i) Most candidates gave a correct answer here, although a number just quoted 'use a fume cupboard' which was insufficient for the mark.
- (ii) There seemed to be a lot of confusion here, with some candidates referring to HBr as red-brown and others to a precipitate forming. The Examiners were looking for observations in order to award credit.
- (iii) The calculations were mostly done well, with a few candidates getting signs the wrong way round.
- (iv) Most candidates knew that the H–Br bond is weaker than the H–C $\equiv$ N bond.

(b)

- (i) Although most candidates gave a correct answer here, there were still significant numbers who included water or a catalyst.
- (ii) This was mostly done correctly, with those who used incorrect signs in **(a)(iii)** gaining credit for error carried forward.
- (iii) Many candidates gave a correct answer here.

(c)

- (i) Most candidates clearly knew what the term *homolytic fission* meant, but some found it difficult to explain. A sketch might have helped them be more precise in their explanation.
  - (ii) Only a minority of candidates identified the  $\bullet\text{CH}_2\text{Cl}$  radical giving a reason.
- (d) Most candidates did not draw four correct isomers, two of which contained chiral carbon atoms.

### Question 2

- (a)
- (i) A pleasing number of candidates gave correct orders with respect to the three reactants. For those who made errors 'error carried forward' as applied in the remainder of the question.
  - (ii) Almost all candidates gave a correct rate equation consequential on their answer to (i).
  - (iii) This part proved less easy with a much smaller proportion of candidates giving correct units.
  - (iv) This could have been deduced by examining the data in the table provided but some candidates chose to carry out complex calculations – not always correctly.
- (b)
- (i)(ii) The concentration calculations were rarely all correct, with a significant number of candidates not including  $2x$  in the  $[\text{CH}_3\text{OH}]$  column. Once again 'error carried forward' credit was awarded.
  - (iii) Candidates generally wrote correct expressions here although some forgot that the term for  $[\text{CH}_3\text{OH}]$  should be squared. Units were only correct in a minority of cases.
  - (iv) The value of the equilibrium constant was marked according to the expression the candidates gave in (iii), and most gained credit here.

### Question 3

- (a) Many candidates ignored the instruction to label their sketch. The diagram needed to have both correct shape and symmetry with respect to the axes. Those who chose to show  $d_{z^2}$  orbitals often drew poor diagrams.
- (b)
- (i) It was essential here to show both the five degenerate d-orbitals in the isolated atom, and the effect on these of forming an octahedral complex. Many did not do this and others showed a 3:2 rather than a 2:3 split.
  - (ii) This area did not appear to be very well understood by candidates. A significant number of candidates stated that the colour of transition metal ions is due to the light that they emit. Even those who knew that the colour was caused by absorption of light often gave very vague answers for the reasons different colours exist.
- (c)
- (i)(ii) Most candidates correctly calculated the two oxidation numbers.
  - (iii) The application of knowledge of octahedral complexes proved difficult for many. Many candidates did not use the structure of the ethanedioate bidentate ion given in the stem in deducing the displayed formula of the complex.
  - (iv) The reactants and products were given, but a significant number of candidates were unable to balance the equation.

### Question 4

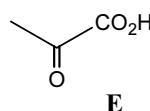
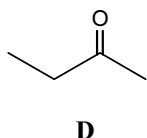
This question proved to be one of the more challenging on the paper with few high scoring answers. There seemed to be some confusion over Brønsted-Lowry acids and bases.

- (a)
- (i) Most candidates gained credit for the equation.
  - (ii) From the number of incorrect answers here it seemed that a lot of candidates guessed the order.
  - (iii) Given the above, correct answers were rare here. Candidates were expected to know that alkyl groups were electron-donating (not 'repelling') and that in phenylamine the lone pair is delocalised over the benzene ring.
- (b)
- (i) Many candidates wrote an equation ionising the phenol without the presence of a soluble base.
  - (ii) In this part there seemed to be confusion over the direction of change of  $K_a$  and  $pK_a$ . As a result candidates found it difficult to explain the difference in the two  $pK_a$  values.
  - (iii) It was expected that candidates would place a tick against  $pK_a$  1.0.
  - (iv) The explanation could be deduced from the table in (i) which shows the presence of the nitro group in nitrophenol reducing the  $pK_a$  value of phenol by approximately 3 suggesting that in the case of the phenylammonium ion the  $pK_a$  value should also be reduced by approximately 3. It could also have been argued on the basis that electron-withdrawing groups increase the acidity of molecules.
- (c)
- (i) A number of candidates did not correctly draw **B**, the phenyldiazonium cation. The most common error was the omission of the positive charge on the first nitrogen atom.
  - (ii) This area of synthetic chemistry was not well remembered with only a small number of candidates giving correct reagents and conditions for the three steps. Many candidates gave 'reflux' as the condition in all three steps, whilst others seemed to think that using concentrated acids would be required.

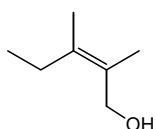
### Question 5

By contrast this question was answered much more successfully.

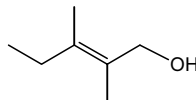
- (a)
- (i) Examiners were looking for C=C double bonds or alkenes here.
  - (ii) Most candidates correctly suggested –OH groups. These could be in alcohols or carboxylic acids.
  - (iii) Some candidates just stated carbonyls, when a more precise answer was needed and so were not awarded credit. Methyl ketones or methyl secondary alcohols were required.
  - (iv) The expected answer here was either carbonyls or aldehydes AND ketones, but not just one.
- (b) The results of the tests should have lead candidates to the following structures.



- (c) The Examiners were looking for the following pair of *cis-trans* or geometrical isomers.



cis



trans

## Section B

Questions in this section are designed to test candidates' ability to apply knowledge gained in the study of core chemistry in new situations as well as testing some aspects of applied chemistry topics. For some candidates there seems to be an expectation that they should 'know' the answers to questions posed here rather than needing to deduce the answers from more familiar chemistry.

### Question 6

- (a)
- (i) Most candidates wrote a correct equation here. The most common error was the omission of water as a by-product.
  - (ii) A large number of candidates did not draw a skeletal formula for the glycine dimer.
- (b)
- (i) Many candidates correctly identified  $\alpha$ -helix and  $\beta$ -pleated sheet as the two forms of secondary structure in proteins.
  - (ii) Although most candidates correctly showed an overall structure, far fewer correctly showed the hydrogen bonds within the secondary structures.
- (c) A number of candidates gained full credit here. The most common error was the description given to van der Waals' forces present in the second pair of residues.

### Question 7

- (a) This question was not answered well. A significant number of candidates confused the technique with DNA finger-printing, and those who did not often missed important parts of the apparatus out or did not label it.
- (b) This was generally well answered and even those candidates who were unable to sketch the apparatus for electrophoresis could state the factors that determined both the direction and speed of travel of the amino acids.
- (c)
- (i) This was not well answered and many candidates did not state why hydrogen atoms fail to produce images using X-ray crystallography. It is electron density rather than mass that is the key factor.
  - (ii) Given the above, there were a good number of correct answers to this part, although not everyone could explain the reason why sulfur would show up most clearly.

### Question 8

This has often been the most tricky question for candidates to answer, necessitating a clarity of thought and often requiring the ability to think laterally. On this paper, the chemistry was more clearly linked to 'core chemistry' yet too often candidates gave non-chemical answers which could not be awarded credit.

- (a) It was felt that this should provide a straightforward introduction to the question yet few candidates were able to quote traditional materials which have been replaced by modern polymers. Some even quoted polymers as the 'traditional material'. The expected answer was a natural material or materials that needed a minimum of processing such as paper, hessian or steel for packaging; cotton, wool or silk for fabrics; glass, clay or metal for bottles.

- (b) The disposal of polymers is a major problem to the environment and suitable methods of disposal should be familiar to candidates. Inappropriate answers such as 'put them on a ship and dump them at sea' were seen. A range of reasons for the environmental concerns were accepted such as long lifetime before decomposition and a depletion of resources such as crude oil. Strategies for overcoming the concerns were generally better known by candidates, although some of these were in direct conflict with the environmental concerns.
- (c) Examiners expected candidates to be aware that the burning of polymers containing chlorine could cause the release of  $\text{HCl}$  or dioxins, or that burning those containing nitrogen could form  $\text{HCN}$ .
- (d) A small number of candidates gained full credit on this part. The properties of polymers related to their method of formation should be known to candidates, but many candidates did not identify a thermosetting polymer or did not identify the form of polymerisation that produced it (addition or condensation). Few candidates discussed the structural reasons why a polymer might be thermosetting – little cross-linking of chains, weak bonds between chains.

# CHEMISTRY

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<p>Paper 9701/42 A2 Structured Questions</p>
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## Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

## General Comments

There were a number of excellent answers to this paper. The paper discriminated well, and it was felt that it was successful in rewarding those who had a good knowledge and understanding of the subject.

Most candidates generally wrote legibly, although there were still instances of them not reading the questions carefully enough. For example, in **Question 1(d)** some candidates drew molecular rather than structural or skeletal formulae and in **Question 6(a)(ii)** once again skeletal formulae were often not given.

Examiners found no evidence that candidates had run out of time.

This report should be read in conjunction with the published mark scheme for this paper.

## Comments on Specific Questions

### Section A

#### Question 1

##### (a)

- (i) Most candidates gave a correct answer here, although a number just quoted 'use a fume cupboard' which was insufficient for the mark.
- (ii) There seemed to be a lot of confusion here, with some candidates referring to HBr as red-brown and others to a precipitate forming. The Examiners were looking for observations in order to award credit.
- (iii) The calculations were mostly done well, with a few candidates getting signs the wrong way round.
- (iv) Most candidates knew that the H–Br bond is weaker than the H–Cl bond.

##### (b)

- (i) Although most candidates gave a correct answer here, there were still significant numbers who included water or a catalyst.
- (ii) This was mostly done correctly, with those who used incorrect signs in **(a)(iii)** gaining credit for error carried forward.
- (iii) Many candidates gave a correct answer here.

- (c)
- (i) Most candidates clearly knew what the term *homolytic fission* meant, but some found it difficult to explain. A sketch might have helped them be more precise in their explanation.
  - (ii) Only a minority of candidates identified the  $\bullet\text{CH}_2\text{Cl}$  radical giving a reason.
- (d) Most candidates did not draw four correct isomers, two of which contained chiral carbon atoms.

### Question 2

- (a)
- (i) A pleasing number of candidates gave correct orders with respect to the three reactants. For those who made errors 'error carried forward' as applied in the remainder of the question.
  - (ii) Almost all candidates gave a correct rate equation consequential on their answer to (i).
  - (iii) This part proved less easy with a much smaller proportion of candidates giving correct units.
  - (iv) This could have been deduced by examining the data in the table provided but some candidates chose to carry out complex calculations – not always correctly.
- (b)
- (i)(ii) The concentration calculations were rarely all correct, with a significant number of candidates not including  $2x$  in the  $[\text{CH}_3\text{OH}]$  column. Once again 'error carried forward' credit was awarded.
  - (iii) Candidates generally wrote correct expressions here although some forgot that the term for  $[\text{CH}_3\text{OH}]$  should be squared. Units were only correct in a minority of cases.
  - (iv) The value of the equilibrium constant was marked according to the expression the candidates gave in (iii), and most gained credit here.

### Question 3

- (a) Many candidates ignored the instruction to label their sketch. The diagram needed to have both correct shape and symmetry with respect to the axes. Those who chose to show  $d_{z^2}$  orbitals often drew poor diagrams.
- (b)
- (i) It was essential here to show both the five degenerate d-orbitals in the isolated atom, and the effect on these of forming an octahedral complex. Many did not do this and others showed a 3:2 rather than a 2:3 split.
  - (ii) This area did not appear to be very well understood by candidates. A significant number of candidates stated that the colour of transition metal ions is due to the light that they emit. Even those who knew that the colour was caused by absorption of light often gave very vague answers for the reasons different colours exist.
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- (i)(ii) Most candidates correctly calculated the two oxidation numbers.
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  - (iv) The reactants and products were given, but a significant number of candidates were unable to balance the equation.

#### Question 4

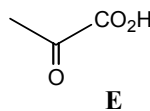
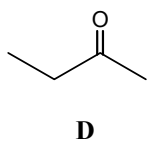
This question proved to be one of the more challenging on the paper with few high scoring answers. There seemed to be some confusion over Brønsted-Lowry acids and bases.

- (a)
- (i) Most candidates gained credit for the equation.
  - (ii) From the number of incorrect answers here it seemed that a lot of candidates guessed the order.
  - (iii) Given the above, correct answers were rare here. Candidates were expected to know that alkyl groups were electron-donating (not 'repelling') and that in phenylamine the lone pair is delocalised over the benzene ring.
- (b)
- (i) Many candidates wrote an equation ionising the phenol without the presence of a soluble base.
  - (ii) In this part there seemed to be confusion over the direction of change of  $K_a$  and  $pK_a$ . As a result candidates found it difficult to explain the difference in the two  $pK_a$  values.
  - (iii) It was expected that candidates would place a tick against  $pK_a$  1.0.
  - (iv) The explanation could be deduced from the table in (i) which shows the presence of the nitro group in nitrophenol reducing the  $pK_a$  value of phenol by approximately 3 suggesting that in the case of the phenylammonium ion the  $pK_a$  value should also be reduced by approximately 3. It could also have been argued on the basis that electron-withdrawing groups increase the acidity of molecules.
- (c)
- (i) A number of candidates did not correctly draw **B**, the phenyldiazonium cation. The most common error was the omission of the positive charge on the first nitrogen atom.
  - (ii) This area of synthetic chemistry was not well remembered with only a small number of candidates giving correct reagents and conditions for the three steps. Many candidates gave 'reflux' as the condition in all three steps, whilst others seemed to think that using concentrated acids would be required.

#### Question 5

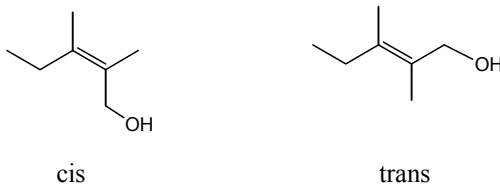
By contrast this question was answered much more successfully.

- (a)
- (i) Examiners were looking for C=C double bonds or alkenes here.
  - (ii) Most candidates correctly suggested –OH groups. These could be in alcohols or carboxylic acids.
  - (iii) Some candidates just stated carbonyls, when a more precise answer was needed and so were not awarded credit. Methyl ketones or methyl secondary alcohols were required.
  - (iv) The expected answer here was either carbonyls or aldehydes AND ketones, but not just one.
- (b) The results of the tests should have lead candidates to the following structures.





- (c) The Examiners were looking for the following pair of *cis-trans* or geometrical isomers.



## Section B

Questions in this section are designed to test candidates' ability to apply knowledge gained in the study of core chemistry in new situations as well as testing some aspects of applied chemistry topics. For some candidates there seems to be an expectation that they should 'know' the answers to questions posed here rather than needing to deduce the answers from more familiar chemistry.

### Question 6

- (a)
- (i) Most candidates wrote a correct equation here. The most common error was the omission of water as a by-product.
  - (ii) A large number of candidates did not draw a skeletal formula for the glycine dimer.
- (b)
- (i) Many candidates correctly identified  $\alpha$ -helix and  $\beta$ -pleated sheet as the two forms of secondary structure in proteins.
  - (ii) Although most candidates correctly showed an overall structure, far fewer correctly showed the hydrogen bonds within the secondary structures.
- (c) A number of candidates gained full credit here. The most common error was the description given to van der Waals' forces present in the second pair of residues.

### Question 7

- (a) This question was not answered well. A significant number of candidates confused the technique with DNA finger-printing, and those who did not often missed important parts of the apparatus out or did not label it.
- (b) This was generally well answered and even those candidates who were unable to sketch the apparatus for electrophoresis could state the factors that determined both the direction and speed of travel of the amino acids.
- (c)
- (i) This was not well answered and many candidates did not state why hydrogen atoms fail to produce images using X-ray crystallography. It is electron density rather than mass that is the key factor.
  - (ii) Given the above, there were a good number of correct answers to this part, although not everyone could explain the reason why sulfur would show up most clearly.

### Question 8

This has often been the most tricky question for candidates to answer, necessitating a clarity of thought and often requiring the ability to think laterally. On this paper, the chemistry was more clearly linked to 'core chemistry' yet too often candidates gave non-chemical answers which could not be awarded credit.

- (a) It was felt that this should provide a straightforward introduction to the question yet few candidates were able to quote traditional materials which have been replaced by modern polymers. Some even quoted polymers as the 'traditional material'. The expected answer was a natural material or materials that needed a minimum of processing such as paper, hessian or steel for packaging; cotton, wool or silk for fabrics; glass, clay or metal for bottles.

- (b) The disposal of polymers is a major problem to the environment and suitable methods of disposal should be familiar to candidates. Inappropriate answers such as 'put them on a ship and dump them at sea' were seen. A range of reasons for the environmental concerns were accepted such as long lifetime before decomposition and a depletion of resources such as crude oil. Strategies for overcoming the concerns were generally better known by candidates, although some of these were in direct conflict with the environmental concerns.
- (c) Examiners expected candidates to be aware that the burning of polymers containing chlorine could cause the release of  $\text{HCl}$  or dioxins, or that burning those containing nitrogen could form  $\text{HCN}$ .
- (d) A small number of candidates gained full credit on this part. The properties of polymers related to their method of formation should be known to candidates, but many candidates did not identify a thermosetting polymer or did not identify the form of polymerisation that produced it (addition or condensation). Few candidates discussed the structural reasons why a polymer might be thermosetting – little cross-linking of chains, weak bonds between chains.

# CHEMISTRY

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Paper 9701/43  
A2 Structured Questions

## Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

## General Comments

There were quite a few excellent answers to this paper. The paper discriminated well, and it was felt that it was successful in rewarding those who had a good knowledge and understanding of the subject.

Candidates generally wrote legibly, and there were fewer instances of them not reading the questions carefully enough. However, in **Question 5** some candidates wrote molecular rather than structural formulae in **(b)(iii)**, and drew structural rather than skeletal formulae in **(c)**.

Examiners found no evidence that candidates had run out of time, although on some scripts **Question 7** was left blank – possibly due to candidates not having revised these topics sufficiently well to allow them to feel confident in answering it.

This report should be read in conjunction with the published mark scheme for this paper.

## Comments on Specific Questions

### Section A

#### Question 1

- (a) Most candidates answered well here, although some removed the 3d electrons to form the ions, rather than the 4s electrons.
- (b)
- Examiners expected a Le Chatelier type of argument, with the increase in  $[H^+]$  pushing the equilibria to the right, and increasing the  $E^\ominus$  values. Many candidates answered well, although some restricted their answers to a rate of reaction argument.
  - The colour changes were well recalled by most, although some candidates described the change for  $KMnO_4$  as being from purple to pink, confusing it with the end point in a  $KMnO_4$  titration. Purple to *colourless* was the expected answer. If pink was stated instead of colourless, it had to be **very pale** pink (the colour of  $Mn^{2+}(aq)$ ).
- (c)
- Whilst some candidates thought the question was concerned with the reaction between  $SO_2$  and  $KMnO_4$ , most were able to gain credit for the correct equation, and the correct changes in oxidation numbers. Some kept the  $4H^+$  and  $2H_2O$  on each side of the equation; they were allowed credit here, but often this did not allow them to think clearly in **(ii)**.
  - Only a few candidates realised that since their equation in **(i)** did not include  $H^+$  ions, changing the pH of the solution would have no effect.

- (d)
- (i) Most gained credit for the correct equation. The most common errors were to use Sn rather than  $\text{Sn}^{2+}$ , or  $\text{MnO}_4^-$  rather than  $\text{MnO}_2$ , as reactants.
  - (ii) This calculation was set out in steps for the candidates' convenience. The usual errors that occurred were the inversion of the stoichiometric ratio; the  $M_r$  value incorrectly calculated and incorrect powers of 10. Several candidates ended up with a percentage greater than 100, but made no comment on this.

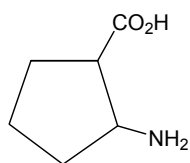
### Question 2

- (a)
- (i) Most candidates mentioned that a ligand contains a lone pair of electrons, but fewer went on to distinguish it from a nucleophile by stating that it bonds with a central (metal) atom or ion.
  - (ii) Almost all candidates recognised that dative bonding was involved here.
- (b)
- (i) The points were generally plotted accurately, although some candidates started their plot at 0.001 rather than 0.01. A straight line should have been drawn through the points – some candidates attempted to draw a curve.
  - (ii) Many candidates incorrectly thought the reaction was 2<sup>nd</sup> order in  $[\text{Cr}(\text{CO})_6]$  and 1<sup>st</sup> order in  $[\text{PR}_3]$ . The more able candidates gave explanations that involved calculating the half-life as being constant for  $\text{Cr}(\text{CO})_6$ , and pointing out the graph was linear for  $\text{PR}_3$ .
  - (iii) The rate equation was marked according to the orders the candidates gave in (ii), and most gained credit here. However, if the incorrect rate equation included *both* reactants, it was impossible to calculate the rate constant accurately, since the concentrations of both reactants in the same run were not known. Several candidates were not careful enough about drawing the tangent of the curve at  $t = 0$ , and so over-estimated the rate, and hence the value of  $k$ .
  - (iv) This part was marked consequentially from the rate equation in (iii).
  - (v) This was also marked according to the rate equation given in (iii). The key point was that since  $[\text{PR}_3]$  does not appear in rate equation, it cannot be in a slow step. Many candidates scored well here.

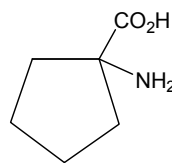
### Question 3

- (a)
- (i) Examiners saw a range of structures for **E**, but many candidates correctly identified it as the aminonitrile.
  - (ii) Only a few candidates worked out the correct structure here of phenylethanal. Most suggested an amino acid, nitrobenzene, phenol or benzene itself.
- (b)
- (i) It was essential here to mention that proteins are polymers of amino acids and many gained credit here.
  - (ii) Many candidates did not show the peptide bond clearly, or do what the question asked, namely to show *two repeat units*. The most common response, the dipeptide was awarded partial credit however. Several candidates used phenylalanine as their amino acid rather than alanine.
- (c)
- (i) Most candidates realised either an acid or an alkali was required here, heated in aqueous solution.

- (ii) This application of knowledge of amide hydrolysis proved difficult for some. Quite a number drew 2-aminocyclopentanoic acid rather than the 1-isomer.



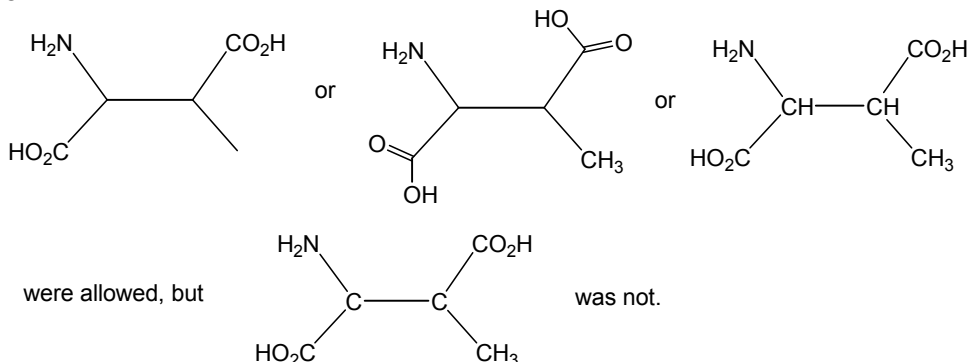
incorrect



correct

Others did not show the correct formula for **H**; skeletal, structural or displayed was acceptable, but not an in-between one.

Thus



- (d) Most drew the correct structure for the zwitterion of alanine in (i), and a good many applied their knowledge well to the three compounds in (ii). The most common mistakes were to add another proton to the CH<sub>3</sub> group on the methylamino phenol, giving Ar-NHCH<sub>4</sub><sup>+</sup>, or to convert the S=O groups into S-O<sup>-</sup> groups.

(e)

- (i) Many wrote the right definition for a buffer, stating that the pH changes only a little (or that a buffer resists, rather than maintains, a change in pH) when a small amount of acid or base is added.
- (ii) Many candidates incorrectly used the alanine anion rather than alanine itself (either the un-ionised molecule or the zwitterion was accepted). Others thought alanine reacted with HCl to give the acid chloride.
- (iii) Many did not appreciate the role of HCO<sub>3</sub><sup>-</sup> ions in the blood. Hydrogen carbonate reacts with both acids and bases. Several thought either haemoglobin or amino acids were the major contributors to the buffering action.
- (iv) Most candidates gained partial credit here; they did not appreciate that the added NaOH would not only form the ethanoate anion, but would also use up the equivalent amount of acid in so doing. Thus the acid/salt ratio is 3:2, and not 5:2.

#### Question 4

- (a) Most candidates gained credit for the equation, although some forgot the ½ before the O<sub>2</sub>. There were a few candidates who thought that the heating of a substance in air inevitably meant that oxygen had to be one of the reagents, and so they wrote equations with O<sub>2</sub> on the left as well as the right.
- (b) Both the trend and its explanation in terms of cation size and polarisation of the anion were well understood by candidates. Some, however, wrote in terms of atomic, rather than cationic, size, and did not specify which ion was undergoing polarisation.
- (c)
- (i) Several candidates thought the formula of lithium carbonate was LiCO<sub>3</sub>. Here again, Examiners saw (balanced) equations with O<sub>2</sub> on the left as well as the right.

- (ii) Many correctly drew attention to the difference in cationic size between  $\text{Li}^+$  and  $\text{Na}^+$ .
- (iii) Most candidates gained credit here, either for describing the brown gas ( $\text{NO}_2$ ) or for stating that a gas was evolved that would relight a glowing splint ( $\text{O}_2$ ).

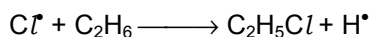
### Question 5

(a) Credit was awarded either for pointing out that alkanes are non-polar, or for mentioning the high strength of the C–H bond. Surprisingly, only a minority of candidates mentioned either of these points.

(b)

(i) Most candidates correctly identified this reaction as a free radical substitution, but electrophilic or nucleophilic were common errors.

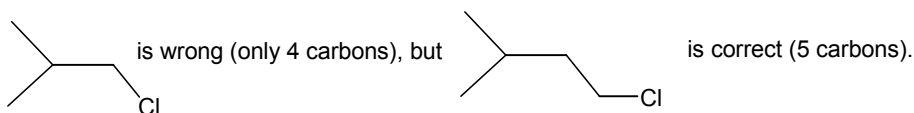
(ii) Most candidates gained credit for the initiation step, but they often only included the first of the two propagation steps, producing the ethyl radical,  $\text{C}_2\text{H}_5^\bullet$ . The product was then formed by the termination step involving  $\text{C}_2\text{H}_5^\bullet$  and  $\text{Cl}^\bullet$ . The other common error was to produce  $\text{H}^\bullet$  in the 'propagation' step:



(iii) Most candidates chose to form their by-products by the combination of two radicals, such as  $\text{C}_2\text{H}_5^\bullet + \text{C}_2\text{H}_5^\bullet$ . Several did not draw the structural formulae of the by-products, only giving their molecular formulae. Others gave the main product,  $\text{C}_2\text{H}_5\text{Cl}$ , as one of the by-products.

(iv) Only the most able candidates gained full credit here. The ratio would be 21:9 (or 7:3) because there are nine primary hydrogen atoms compared to only one tertiary hydrogen.

(c) Many candidates drew structural instead of skeletal formulae, or did not draw the skeletal formulae correctly. Thus



Some candidates incorrectly identified the chiral atoms; there were only two of them in the four structures.

### Section B

Questions in this section are designed to test candidates' ability to apply knowledge gained in the study of core chemistry in new situations as well as testing some aspects of applied chemistry topics. For some candidates there seems to be an expectation that they should 'know' the answers to questions posed here rather than needing to deduce the answers from more familiar chemistry.

### Question 6

(a)

(i) Most candidates correctly identified **K** as the monomer for protein building, due to it containing nitrogen.

(ii) A surprisingly small number of candidates gained credit here; if they chose **J** they often suggested that the polymer was DNA rather than RNA, and if they chose **L** they said the polymer was a 'carbohydrate' (this term, in fact, includes **L** itself), rather than a polysaccharide, starch or cellulose.

(b)

(i) The word covalent was looked for.

- (ii) Although most candidates correctly mentioned hydrogen bonding, some incorrectly included other forms of bonding too, such as ionic or van der Waals'.
  - (iii) Almost all candidates gained credit here, for either ionic, disulfide or van der Waals'.
- (c)
- (i) Most correctly applied the term enzyme to these catalysts.
  - (ii) 'Conditions' were not considered to include inhibitors. Examiners were looking for high temperature, a change in pH or the presence of heavy metal ions. Most candidates did well on this part, and correctly described the type of bonds in the tertiary structure that would be affected by each change in condition.

### Question 7

- (a) Almost all candidates answered this part very well. 'Crystallography' or 'diffraction' had to be included along with 'X-ray' for credit to be awarded. Only NMR was accepted for the second box and either electrophoresis, chromatography or mass spectrometry was allowed for the third.
- (b) Several candidates correctly described the difference in the principles behind these two forms of chromatography; in (i), paper chromatography relies on the partition of the solute between a stationary and a moving solvent, whereas in (ii), thin-layer chromatography makes use of the different tendencies solutes have to be adsorbed onto the solid phase.
- (c)
- (i) Most candidates correctly calculated that there were three carbon atoms in each molecule of **N**.
  - (ii) Many recognised that the equal heights of the M and M+2 peaks suggested that Br was the other element, and in (iii) pointed out that the absence of an M+4 peak suggested only one Br atom per molecule. Some, however, suggested that **N** contained chlorine rather than bromine.
  - (iv) Many realised that the empirical formula had to be C<sub>3</sub>H<sub>7</sub>Br, but fewer were able to interpret the spectrum to identify **N** as 2-bromopropane.

### Question 8

This has traditionally been the most tricky question for candidates to answer, necessitating a clarity of thought and often requiring the ability to think laterally. Gratifyingly, quite a number of candidates this year scored highly on this question.

- (a)
- (i) Many candidates realised that the soluble form would act more quickly.
  - (ii) Candidates could argue this in one of two ways; either that **P** would act more rapidly because it would take time to dissolve the casing of **Q**, or that **Q** would act more rapidly because once the casing had dissolved, the drug, being in the form of tiny granules, would dissolve and react quickly. Either suggestion gained credit. Quite a number of candidates were confused as to how medicines taken orally reach their targets; some said that **Q** would act the most rapidly because the little granules would flow through the gut wall and bloodstream and react directly with the target organ.
  - (iii) It was expected that candidates would know that the stomach is acidic whereas the intestines are alkaline, so to survive the stomach the gel casing had to be stable to acid.
- (b) Both the speed of action and the accuracy of the dose are increased by using the intravenous route. Other factors that could have been mentioned were that some drugs are unstable under acidic conditions of the stomach, or could be broken down into non-potent forms in the gut, before being absorbed.
- (c)
- (i) Most candidates gained credit for 'condensation polymerisation'.

- (ii) Either hydrogen-bonds or van der Waals' were accepted here; ionic does not occur and covalent would already be taken up with bonding to the drug.
- (iii) Rather than acting as an inhibitor for the enzyme, as some candidates suggested, the attachment of PEG to the drug molecule will alter the overall shape of the drug molecule and cause a less effective fit in the enzyme's active site.
- (iv) Most candidates correctly identified 'hydrolysis' as the relevant reaction.



# CHEMISTRY

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**Paper 9701/51**

**Planning, Analysis and Evaluation**

## Key messages

- As always, candidates should be encouraged to read each question carefully before answering.
- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.
- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

## General Comments

The paper successfully identified those candidates with high level practical and graphical skills.

In **Question 1(c)** the stem of the question provided five bullet point prompts to expected responses. Candidates should be made aware that the examination answers require these points to be addressed. Candidates should be advised to work out the focus of their plan first rather than working it out as they go along.

In **Question 2**, two points about data tables are common every session. Firstly, candidates need to fully label each new column used. Secondly, the data needs to be correctly quoted to, either a specified number of decimal places or significant figures. In this examination, the data requirement was for three significant figures. There was evidence that some candidates wrongly believe that the number of decimal places is the same as significant figures. Candidates should be advised to look for the required significance/decimal places before calculating any data.

Two factors need to be taken into account when scaling the axes. The points need to be plotted within at least half of each axis and the scale should be reasonable to facilitate accurate plotting. It seems that candidates need advising to fit a reasonable scale into the grid first that uses at least half of each axis. In this examination, unreasonable scales of 0.006, 0.008 and 0.011 units to 10 small squares inevitably led to plotting errors. Some scales of 1/T only allowed plotting of points over two large squares. Some other scales did not extend to cover all of the points.

## Comments on Specific Questions

### Question 1

#### (a)

- (i) Most candidates, using the first two lines in the question, correctly predicted an increase in solubility as temperature increases. In the explanation the majority of the candidates realised that potassium nitrate needs energy to dissolve. The reference to endothermicity may have led some candidates into reaction kinetics, answering in terms of rate of reaction and the frequency of collisions. A few candidates incorrectly predicted a decrease in solubility.
- (ii) The requirement of the sketch graph was to graphically illustrate the prediction made earlier. Most candidates correctly sketched a line of positive gradient. The axes of a sketch graph always need to be labelled as requested in the stem of the question. It is always advisable to label the *x*-axis as the independent variable and the *y*-axis with the dependent variable which in this case were temperature and solubility respectively. Some candidates had these inverted. Most candidates had temperature as one of the labels. Some candidates had mass, amount or concentration instead of solubility which did not relate to the prediction.

- (b) Most candidates identified the independent and dependent variables correctly. On occasion these answers conflicted with the labels on the axes above.
- (c) Many candidates did not address the intent of the question – to determine solubility at various solution temperatures. Quite a few had descriptions that related to an enthalpy change where the candidate measured an initial and a final temperature leading to a temperature change. There are many ways that the solubility of a salt at various temperatures can be determined. Often there seemed to be a combination of different approaches or, more usually, an unstructured addition of potassium nitrate to water that then lacked a consideration of solubility. Candidates should be advised to read the bullet points provided in the question and use them to structure their answer. Then candidates need to focus on the object of the experiment before committing pen to paper. Usually within the examination there are blank pages or spaces where plans may be outlined.

There was a variable use of the bullet points provided. It was pleasing to see that most candidates elected to run five or more experiments and over a suitable range of temperature (or mass) thus gaining credit. These two marking points were sometimes awarded from information in the table in (e). Most candidates stated a mass of salt and volume of water, although many did not specify how these were measured and without any basis for that choice. Some candidates believed the potassium nitrate was a liquid (or solution). Given that no solubility data was provided, then a short description of a trial to determine suitable quantities would have been appropriate as prompted by the second bullet point. Very few candidates addressed this point. As a generality, most candidates specified quantities but not all described their measurement although most responded to the stirrer prompt to include stirring. Heating by water bath was common but this often led candidates into measuring the temperature of the bath rather than the solution, these two not necessarily being the same.

A cornerstone of solubility determination is to commence with a mixture of solvent and solute. Unfortunately many candidates commenced with just heating the solvent alone and then adding the solute, not realising that this would produce a temperature change or considering whether the result was a solution (saturated or otherwise) or a mixture, thereby missing the point of solubility. It was necessary to take the temperature of the mixture or solution at the point of saturation however that was achieved.

There are some occasions where an inappropriate word was used, for example some candidates used 'boil' when 'heat' would have been correct and 'react' when 'dissolve' was needed.

- (d) The most hazardous item was hot apparatus which needed to be handled with heatproof gloves or appropriate holders.
- (e) The required column headings in a table of results were mass of salt dissolved, volume/mass of water, temperature of solution and solubility along with their units of /g, /cm<sup>3</sup>, /°C, /g / 100 g. The descriptions sometimes lacked specificity. Most candidates included correct units.

## Question 2

- (a) Candidates should be encouraged to read the text preceding the table before completing it. There was a great deal of information which the candidates needed to use in their answers. There are two common errors in headings and data that occur regularly.

Each column heading needs three things; a description (e.g. rate), a unit (e.g. /s<sup>-1</sup>) and an expression to calculate the data (e.g. 1/time) as required. Unusually these headings were supplied in the stem of the question and most candidates had adequate headings. The unit for rate was s<sup>-1</sup> and for 1/T, K<sup>-1</sup>. Log values have no unit. Unfortunately some candidates gave s<sup>-1</sup> as a unit for the log.

Also stated was a requirement for a specific number of significant figures. There has been a general misunderstanding of the difference between significant figures, decimal places and also trailing zeros. In this case the requirement was for three significant figures in all data. It was pleasant to see that most candidates in this examination successfully quoted the data to three significant figures including proper use of trailing zeros e.g. 0.00310. Those who erroneously recorded 1/T to three decimal places instead had all the values to be 0.003. These values, of course, would produce a plot of a single straight line which should have alerted the candidates to

check what they had done. There was also some evidence of truncation of data rather than correct rounding.

The values of  $\log_{10}(\text{rate})$  being negative did not cause difficulty for most candidates. The values of  $1/T$  were often correctly reported in the form  $0.00341$  or  $3.41 \times 10^{-3}$  with the correct unit in the heading as  $\text{K}^{-1}$ . Some candidates gave values as  $3.41$  but gave a  $10^{-3}$  ambiguously in the heading. The only acceptable way to give that was within the unit as  $/10^{-3} \text{K}^{-1}$ .

- (b) When plotting data the first consideration is to identify the independent variable and assign it to the x-axis. In this case the independent variable was  $1/T$  and most candidates correctly identified that. The arrangement of the plot was fairly unusual including increasingly negative values of  $\log_{10}(\text{rate})$  on the y-axis. Thus the y-axis needed to start with a value of around  $-1.0$  at the top of the grid then running down through more negative values to around  $-1.9$ . Most candidates made a very good job of constructing this downward increasingly negative axis. Some candidates plotted the  $\log_{10}(\text{rate})$  values in the reverse direction and some others reversed the direction of the  $1/T$  scale.

The  $\log_{10}(\text{rate})$  axis was usually well scaled as was  $1/T$ ; however some candidates chose too large a scale for  $1/T$  which meant that the plotted points did not extend over half of the grid. Both axes need to be scaled for the plotted points (including the origin if appropriate) to cover half of each axis. There were some inappropriate scales used which made some plotting inaccurate. It would aid accuracy in plotting if candidates would mark (with a small line) the grid line that corresponds to a particular scale value. Most points, including the two anomalies, were plotted correctly, although the point at  $0.00305$  was often mis-plotted as  $0.003005$ . Most lines of best fit were satisfactory. Some candidates did not use either both or one of the axes required by the question at the top of the grid.

- (c) If correctly plotted there were two anomalous points but credit was given for mis-plots provided no more than five anomalies were claimed and the most anomalous point was included. The reasons for the anomalies need to be based in errors inherent in the procedure such as the difficulty in deciding when the solution became opaque rather than an operator error such as spillage. Most candidates who attempted this properly linked their reasons to the relevant point even if the given reason was incorrect. Many provided ambiguous answers such as "the time was wrong". Some candidates had the reasons crossed over perhaps because rate was the inverse of time.
- (d) In this case reliability revolved around most experimental points lying on a line. The statement of a straight line with no reference to points was insufficient since a straight line could be drawn through scattered (unreliable) points. If the candidate had widely scattered points then the reverse argument was acceptable as was the lack of repeats.
- (e) Most candidates drew good construction lines on the graph. Usually the candidates read the correct values from their scales for their intercepts. If the candidates scaled the x-axis with values like  $3.41$  with a  $10^{-3}$ , then sometimes the  $10^{-3}$  was dropped in the intercepts and also in the subsequent calculation. Given plotting with the correct axes, the slope was negative and would calculate so. A typical slope was  $-1.70 - (-1.25)/(3.33 - 2.90) \times 10^{-3} = -0.45/4.3 \times 10^{-4} = -1046.5$ . This was a reasonably complex calculation where a number of candidates did not correctly calculate the "double negative" and gave a positive value. Sometimes the relation between the x- and the y-values was inverted which also led to a positive result.
- (f) The correct response here was to substitute the slope into  $\text{slope} = -E_A/19$ . Many candidates did not properly extract the expression for the slope from the  $y = mx$  format of the given expression and instead equated slope to  $-E_A/19T$ . Some candidates inserted co-ordinates into the expression which was not using the value of slope as required by the question. Correct calculation required the correct use of the negative signs in the slope and the expression to give a positive value for  $E_A$ .
- (g) The majority of candidates correctly reported that kinetic energy (or speed) would increase with increasing temperature. Also, most correctly quoted an increased frequency of collision (rather than more collisions) or more collisions with an energy exceeding the activation energy. Generally speaking this question was answered well.

# CHEMISTRY

Paper 9701/52

Planning, Analysis and Evaluation

## Key messages

- As always, candidates should be encouraged to read each question carefully before answering.
- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.
- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

## General Comments

The paper successfully identified those candidates with high level practical and graphical skills.

In **Question 1(c)** the stem of the question provided five bullet point prompts to expected responses. Candidates should be made aware that the examination answers require these points to be addressed. Candidates should be advised to work out the focus of their plan first rather than working it out as they go along.

In **Question 2**, two points about data tables are common every session. Firstly, candidates need to fully label each new column used. Secondly, the data needs to be correctly quoted to, either a specified number of decimal places or significant figures. In this examination, the data requirement was for three significant figures. There was evidence that some candidates wrongly believe that the number of decimal places is the same as significant figures. Candidates should be advised to look for the required significance/decimal places before calculating any data.

Two factors need to be taken into account when scaling the axes. The points need to be plotted within at least half of each axis and the scale should be reasonable to facilitate accurate plotting. It seems that candidates need advising to fit a reasonable scale into the grid first that uses at least half of each axis. In this examination, unreasonable scales of 0.006, 0.008 and 0.011 units to 10 small squares inevitably led to plotting errors. Some scales of 1/T only allowed plotting of points over two large squares. Some other scales did not extend to cover all of the points.

## Comments on Specific Questions

### Question 1

(a)

- (i) Most candidates, using the first two lines in the question, correctly predicted an increase in solubility as temperature increases. In the explanation the majority of the candidates realised that potassium nitrate needs energy to dissolve. The reference to endothermicity may have led some candidates into reaction kinetics, answering in terms of rate of reaction and the frequency of collisions. A few candidates incorrectly predicted a decrease in solubility.
- (ii) The requirement of the sketch graph was to graphically illustrate the prediction made earlier. Most candidates correctly sketched a line of positive gradient. The axes of a sketch graph always need to be labelled as requested in the stem of the question. It is always advisable to label the *x*-axis as the independent variable and the *y*-axis with the dependent variable which in this case were temperature and solubility respectively. Some candidates had these inverted. Most candidates had temperature as one of the labels. Some candidates had mass, amount or concentration instead of solubility which did not relate to the prediction.

- (b) Most candidates identified the independent and dependent variables correctly. On occasion these answers conflicted with the labels on the axes above.
- (c) Many candidates did not address the intent of the question – to determine solubility at various solution temperatures. Quite a few had descriptions that related to an enthalpy change where the candidate measured an initial and a final temperature leading to a temperature change. There are many ways that the solubility of a salt at various temperatures can be determined. Often there seemed to be a combination of different approaches or, more usually, an unstructured addition of potassium nitrate to water that then lacked a consideration of solubility. Candidates should be advised to read the bullet points provided in the question and use them to structure their answer. Then candidates need to focus on the object of the experiment before committing pen to paper. Usually within the examination there are blank pages or spaces where plans may be outlined.

There was a variable use of the bullet points provided. It was pleasing to see that most candidates elected to run five or more experiments and over a suitable range of temperature (or mass) thus gaining credit. These two marking points were sometimes awarded from information in the table in (e). Most candidates stated a mass of salt and volume of water, although many did not specify how these were measured and without any basis for that choice. Some candidates believed the potassium nitrate was a liquid (or solution). Given that no solubility data was provided, then a short description of a trial to determine suitable quantities would have been appropriate as prompted by the second bullet point. Very few candidates addressed this point. As a generality, most candidates specified quantities but not all described their measurement although most responded to the stirrer prompt to include stirring. Heating by water bath was common but this often led candidates into measuring the temperature of the bath rather than the solution, these two not necessarily being the same.

A cornerstone of solubility determination is to commence with a mixture of solvent and solute. Unfortunately many candidates commenced with just heating the solvent alone and then adding the solute, not realising that this would produce a temperature change or considering whether the result was a solution (saturated or otherwise) or a mixture, thereby missing the point of solubility. It was necessary to take the temperature of the mixture or solution at the point of saturation however that was achieved.

There are some occasions where an inappropriate word was used, for example some candidates used 'boil' when 'heat' would have been correct and 'react' when 'dissolve' was needed.

- (d) The most hazardous item was hot apparatus which needed to be handled with heatproof gloves or appropriate holders.
- (e) The required column headings in a table of results were mass of salt dissolved, volume/mass of water, temperature of solution and solubility along with their units of /g, /cm<sup>3</sup>, /°C, /g / 100 g. The descriptions sometimes lacked specificity. Most candidates included correct units.

## Question 2

- (a) Candidates should be encouraged to read the text preceding the table before completing it. There was a great deal of information which the candidates needed to use in their answers. There are two common errors in headings and data that occur regularly.

Each column heading needs three things; a description (e.g. rate), a unit (e.g. /s<sup>-1</sup>) and an expression to calculate the data (e.g. 1/time) as required. Unusually these headings were supplied in the stem of the question and most candidates had adequate headings. The unit for rate was s<sup>-1</sup> and for 1/T, K<sup>-1</sup>. Log values have no unit. Unfortunately some candidates gave s<sup>-1</sup> as a unit for the log.

Also stated was a requirement for a specific number of significant figures. There has been a general misunderstanding of the difference between significant figures, decimal places and also trailing zeros. In this case the requirement was for three significant figures in all data. It was pleasant to see that most candidates in this examination successfully quoted the data to three significant figures including proper use of trailing zeros e.g. 0.00310. Those who erroneously recorded 1/T to three decimal places instead had all the values to be 0.003. These values, of course, would produce a plot of a single straight line which should have alerted the candidates to

check what they had done. There was also some evidence of truncation of data rather than correct rounding.

The values of  $\log_{10}(\text{rate})$  being negative did not cause difficulty for most candidates. The values of  $1/T$  were often correctly reported in the form  $0.00341$  or  $3.41 \times 10^{-3}$  with the correct unit in the heading as  $\text{K}^{-1}$ . Some candidates gave values as  $3.41$  but gave a  $10^{-3}$  ambiguously in the heading. The only acceptable way to give that was within the unit as  $/10^{-3} \text{K}^{-1}$ .

- (b) When plotting data the first consideration is to identify the independent variable and assign it to the x-axis. In this case the independent variable was  $1/T$  and most candidates correctly identified that. The arrangement of the plot was fairly unusual including increasingly negative values of  $\log_{10}(\text{rate})$  on the y-axis. Thus the y-axis needed to start with a value of around  $-1.0$  at the top of the grid then running down through more negative values to around  $-1.9$ . Most candidates made a very good job of constructing this downward increasingly negative axis. Some candidates plotted the  $\log_{10}(\text{rate})$  values in the reverse direction and some others reversed the direction of the  $1/T$  scale.

The  $\log_{10}(\text{rate})$  axis was usually well scaled as was  $1/T$ ; however some candidates chose too large a scale for  $1/T$  which meant that the plotted points did not extend over half of the grid. Both axes need to be scaled for the plotted points (including the origin if appropriate) to cover half of each axis. There were some inappropriate scales used which made some plotting inaccurate. It would aid accuracy in plotting if candidates would mark (with a small line) the grid line that corresponds to a particular scale value. Most points, including the two anomalies, were plotted correctly, although the point at  $0.00305$  was often mis-plotted as  $0.003005$ . Most lines of best fit were satisfactory. Some candidates did not use either both or one of the axes required by the question at the top of the grid.

- (c) If correctly plotted there were two anomalous points but credit was given for mis-plots provided no more than five anomalies were claimed and the most anomalous point was included. The reasons for the anomalies need to be based in errors inherent in the procedure such as the difficulty in deciding when the solution became opaque rather than an operator error such as spillage. Most candidates who attempted this properly linked their reasons to the relevant point even if the given reason was incorrect. Many provided ambiguous answers such as "the time was wrong". Some candidates had the reasons crossed over perhaps because rate was the inverse of time.
- (d) In this case reliability revolved around most experimental points lying on a line. The statement of a straight line with no reference to points was insufficient since a straight line could be drawn through scattered (unreliable) points. If the candidate had widely scattered points then the reverse argument was acceptable as was the lack of repeats.
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## General Comments

In **Question 1** the effusion experiment may well have been unfamiliar to many candidates but credit was given for the usual experimental techniques necessary to obtain reliable data, e.g. temperature control, identical gas volumes or timings and the need to repeat measurements. The stem of the question did provide five bullet point prompts to expected responses and candidates should attempt to address these points.

The quality of answers to **Question 2** showed an improvement over recent years. The data was such that it facilitated the choosing of appropriate scales for the graph.

## Comments on Specific Questions

### Question 1

- (a)
- (i) Most candidates received credit for stating that the rate decreased as the  $M_r$  increased. Given the wording of the stem of the question, on this occasion candidates who suggested that the rate of effusion was constant did receive credit.
- (ii) Sketch graphs were usually correctly drawn with the dependent variable, rate, on the  $y$ -axis and the independent variable,  $M_r$ , on the  $x$ -axis. Unfortunately, some candidates did suggest that a  $M_r$  of zero was possible by intercepting the  $y$ -axis and/or a rate of zero by intercepting the  $x$ -axis.
- (b) The independent ( $M_r$ ) and dependent variables (rate or time of effusion) were usually correctly identified
- (c) A number of candidates did not understand that effusion caused gas to leave the syringe and suggested timings for gas to be collected in the syringe. Others suggested that gas from the syringe should be collected over water. Both of these were incorrect approaches. Others described methods of preparing the gases. The best answers recognised the need to flush the syringe with each gas prior to each experiment, the need to ensure that the syringe was clamped in the same orientation, not horizontal, in each experiment and the need to ensure that the piston was moving freely prior to starting timing. Temperature control, identical gas volumes or timings and the need for repeats were also expected techniques.
- (d) Credit was given for recognising that hydrogen and butane are flammable and that chlorine is toxic. The expected precautions were no naked flames for the flammable gases and the use of a fume cupboard for chlorine. Oxygen was sometimes suggested as being flammable and comments such as "carbon dioxide may be harmful to health" were not regarded as being specific enough to gain credit.

- (e) Answers to this question were generally good. Column headings were clear and the units were usually given in the correct form. The molecular formula of butane was occasionally incorrect, leading to an incorrect value of  $M_r$ .

## Question 2

- (a) Generally the table was completed well. The need to calculate data to 2 significant figures was understood by most candidates. Occasionally expressions, e.g.  $C-A/207$ , were omitted from the column heading.  $M_r$  appeared rather than  $A_r$  in some expressions but most candidates were able to calculate the correct values for the number of moles of lead and oxygen atoms.
- (b) In this particular question it did not matter whether the moles of lead or oxygen appeared on the y-axis and most candidates suggested suitable scales for the graph. A significant number, however, did not appreciate that the origin was a sensible point to plot and produced scales which prevented the drawing of the line to this point. Generally the standard of plotting was good but some straight lines were poorly drawn. The use of short rulers producing lines of two halves and blunt pencils are still being seen.
- (c) Anomalies were marked well but explanations were not often correct. There were two clearly anomalous points, one due to incomplete reduction or re-oxidation on cooling and one due to material being carried away by the stream of hydrogen. No credit was given for incomplete combustion or burning. Occasionally, otherwise correct reasons were assigned to the wrong points.
- (d) The expected answer here was that the procedure was reliable since most of the plotted points lay on or close to the line of best-fit. The fact that the line passed through the origin was of no value as a lone statement.
- (e) Construction lines were usually drawn on the graph and correct intercepts usually given. Calculations of the gradient were often correct.
- (f) Most candidates appreciated that the slope of the graph gave the ratio of lead to oxygen atoms (or vice versa) in the oxide but often they wanted to approximate the correct value of 1.33 or 0.75:1 to an incorrect 1:1. This resulted in a suggested formula of PbO rather than the correct  $Pb_3O_4$ .