

# CHEMISTRY

Paper 9701/01  
Multiple Choice

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

## General Comments

For this paper, the mean score was 22.4 (56.0%), and the standard deviation of the scores was 7.50 (18.8%), indicating that the paper discriminated very satisfactorily among candidates.

The first 30 questions were simple completion items: **Questions 31 to 40** were three-statement multiple completion items.

## Comments on Individual Questions

Only three questions had a facility above the design limit: **Questions 1** and **2** by a small margin, both set as 'easy starters', and **Question 37**, on the function of cracking alkanes – candidates' success in this item is welcome as it is not a topic often covered in examinations.

Of the other questions, only two did not perform as expected. **Question 20** asked for the number of *cis-trans* isomers of gamma-linoleic acid, a continuous ('straight') chain compound having three asymmetric carbon-carbon double bonds. The most popular response, which included some of the more able candidates, was option **B**, giving 6 as the number – by adding together 2 for each *cis-trans* centre; this was followed by **A**,

giving 3 as the number – by adding together the number of centres; and the key **C** was only chosen by 23% of candidates, recognizing that the symmetry of each centre impacts on the others, and that the answer is  $2^3 = 8$ .

**Question 28** involved two processes: first the breakdown by hot concentrated acidified  $\text{KMnO}_4$  of carvone, a cyclic unsaturated ketone, followed by the reaction of the product with 2,4-dinitrophenylhydrazine reagent. There was an almost equal uptake of options **A**, **B** and **C**, so that the key **C** did not show good discrimination among the ability range of candidates. It is clear that many candidates did not correctly deduce the nature of the breakdown of carvone under these oxidative conditions.

Although it performed satisfactorily, **Question 19** deserves comment. Candidates were asked to give the number of chiral centres in the steroid testosterone: its skeletal formula was given. There was an almost equal choice between the answers 2, 3 and 6 – the correct answer being 6. It would appear that most candidates focused on the positions where there are substituent groups on the ring system, which indeed are chiral centres, but omitted those carbon atoms within the ring system that possess chirality.

**Location Entry Codes**

As part of CIE's continual commitment to maintaining best practice in assessment, CIE has begun to use different variants of some question papers for our most popular assessments with extremely large and widespread candidature. The question papers are closely related and the relationships between them have been thoroughly established using our assessment expertise. All versions of the paper give assessment of equal standard.

The content assessed by the examination papers and the type of questions are unchanged.

This change means that for this component there are now two variant Question Papers, Mark Schemes and Principal Examiner's Reports where previously there was only one. For any individual country, it is intended that only one variant is used. This document contains both variants which will give all Centres access to even more past examination material than is usually the case.

The diagram shows the relationship between the Question Papers, Mark Schemes and Principal Examiner's Reports.

Question Paper	Mark Scheme	Principal Examiner's Report
Introduction	Introduction	Introduction
First variant Question Paper	First variant Mark Scheme	First variant Principal Examiner's Report
Second variant Question Paper	Second variant Mark Scheme	Second variant Principal Examiner's Report

**Who can I contact for further information on these changes?**

Please direct any questions about this to CIE's Customer Services team at: [international@cie.org.uk](mailto:international@cie.org.uk)

# CHEMISTRY

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<p>Paper 9701/21</p> <p>AS Structured Questions</p>
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## General comments

This paper was intended to test candidates' knowledge of some of the practical aspects of AS Level chemistry and their understanding of some of the theoretical elements of the syllabus. Examiners felt that, while most candidates were able to demonstrate some positive achievement, there were fewer very good answers than last year.

Chemistry has a significant factual content and parts of each question asked candidates to recall knowledge. There were many good answers to individual questions but few candidates demonstrated a consistent level of knowledge across all five questions.

For many candidates, the poorest answers were given to **Question 4** or **Question 5**. In the last few years Examiners have been impressed with the standard of answers to organic chemistry questions but felt, on this occasion, that recent progress has not been maintained.

Answers to the calculations in **Questions 1** and **3** were often poorly done, with many candidates failing to show clearly the steps in their calculations. Centres are reminded that the rubric for this paper reminds each candidate that 'You may lose marks if you do not show your working...' Examiners penalised candidates who failed to show working.

The handwriting of some candidates continues to cause Examiners some concern. This was particularly evident in some of the answers to the calculations, where it was impossible to read some of the numbers, and in the state symbols in the equation in **Question 2(a)** where Examiners were unable to distinguish between (g) and (s). If an answer cannot be read, no marks can be awarded.

## Comments on specific questions

### Question 1

Examiners expect AS Level candidates to be able to deduce the electronic configuration of elements and to work out 'dot-and-cross' diagrams of simple compounds. These parts of this question were generally well answered but the sections that were concerned with observation and calculation were less well done.

- (a) The majority of candidates gave a correct configuration for aluminium but fewer gave a correct configuration for titanium.
- (b)(i) Examiners expected candidates to describe what happens when chlorine is passed over heated aluminium to form aluminium chloride. A surprising number used a reagent other than chlorine and many candidates made no mention of heat being necessary.
- (ii) Very few candidates were able to give a complete description of the changes that take place in this reaction.
- (iii) There were many good, clear 'dot-and-cross' diagrams. Some candidates failed to include all of the outer electrons and were penalised, as were those who gave a diagram for  $AlCl_3$ . A small number of candidates wrongly gave diagrams which included an  $Al-Al$  bond.
- (c) Only a very small number of candidates answered this correctly. Chlorine is a strong oxidising agent and copper(I) chloride will not be formed by direct combination of the elements.

- (d)(i) Most candidates were able to do this calculation correctly. The most common error was to use the proton number of titanium rather than its relative atomic mass. The correct answer is given below.

$$n(\text{Ti}) = \frac{0.72}{47.9} = 0.015 \text{ moles}$$

- (ii) Fewer candidates calculated the amount, in moles, of chlorine atoms correctly. Many candidates used the relative molecular mass of chlorine rather than its relative atomic mass in their calculation. Others used the mass of titanium chloride (2.85 g) rather than subtracting the mass of titanium from this figure. The correct answer is given below.

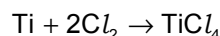
$$n(\text{Cl}) = \frac{(2.85 - 0.72)}{35.5} = 0.060 \text{ moles}$$

- (iii) Many candidates struggled with this part of the calculation. Some appeared to have decided that the correct formula of titanium chloride was  $\text{TiCl}_2$  and set out to prove it. Others struggled with some very strange ratios which should have alerted them to the fact that their calculation was probably wrong. The correct answer is given below.

$$0.015 : 0.060 = 1 : 4$$

empirical formula of **A** is  $\text{TiCl}_4$

- (iv) The equation for the formation of **A** is as follows.



- (e) The majority of candidates correctly deduced that the bonding in  $\text{TiCl}_4$  is covalent. Fewer were able to state clearly that the structure is simple molecular. Some candidates confused covalent bonds within molecules with the weak inter-molecular forces between them while others appeared to think that "tetrahedral" was an appropriate description of the structure. A small number made contradictory statements such as 'titanium chloride molecules are held together by ionic bonds' and were penalised.

## Question 2

This question tested candidates' understanding of ionisation energies and oxidation numbers and their knowledge of the reactions of two magnesium compounds.

Many candidates scored high marks but those who did not usually lost marks in **part (b)**.

- (a)(i) Most candidates gave a correct equation, the main errors being to give an equation involving Mg, or an equation involving  $\text{Mg}^+$  but including two electrons.
- (ii) This part was less well answered with many candidates giving an  $E^\ominus$  value, despite the units being given in the question. The other common error was a failure to include the + sign as the question required.

The correct value is  $+(736 + 1450) = +2186 \text{ kJ mol}^{-1}$ .

- (b) Examiners expect candidates to be able to describe what happens when certain prescribed reactions are carried out. The two reactions in this part are referred to in syllabus **sections 9.1 (i) and (g)** but only a small minority of candidates gave clear and accurate descriptions of both reactions.

Knowledge of the pH of the solution formed in each case was generally better.

- (c)(i) The majority of candidates gave a correct equation.
- (ii) While many candidates correctly calculated the oxidation number of nitrogen as -3 in both compounds, a significant number gave +3 as the oxidation number of nitrogen in ammonia.

## Question 3

The understanding of the principles of chemical equilibria is a key feature of the AS Level chemistry course. Many candidates showed that they could apply le Chatelier's principle correctly to an equilibrium they had not studied. On the other hand, many candidates struggled with the calculation that followed, largely because they appeared to have no systematic method of tackling the problem.

- (a) Most candidates were able to construct the balanced equation.
- (b) While there were many correct answers to this part, a significant number of candidates failed to read the question correctly and gave products that would not be formed if complete combustion had taken place, such as CO, or which were not toxic, such as CO<sub>2</sub>.
- (c) This was generally very well answered with the majority of candidates demonstrating a clear understanding of the principles involved.
- (d)(i) This was poorly answered by many candidates. The reaction to form CO to make methanol on a large scale would remove significant amounts of CO<sub>2</sub> which is associated with global warming.
- (ii) Many candidates really struggled with this calculation and a significant number gave no answer. One problem faced by many of them was how to determine the number moles of each compound present at equilibrium.

A second difficulty was that many candidates who actually attempted the calculation produced a quadratic equation which they then had to solve. The syllabus, in **section 7(f)**, makes it clear that calculations of this type must be solvable without the use of a quadratic equation.

The solution is given below.

	CO <sub>2</sub>	+	H <sub>2</sub>	⇌	CO	+	H <sub>2</sub> O
initial moles	0.50		0.50		0.20		0.20
equil. moles	(0.50-x)		(0.50-x)		(0.20+x)		(0.20+x)
equil. concn.	$\frac{(0.50-x)}{1}$		$\frac{(0.50-x)}{1}$		$\frac{(0.20+x)}{1}$		$\frac{(0.20+x)}{1}$

$$K_c = \frac{[\text{CO}][\text{H}_2\text{O}]}{[\text{CO}_2][\text{H}_2]}$$

$$K_c = \frac{(0.20+x)^2}{(0.50-x)^2} = 1.44$$

taking square roots of both sides of this expression gives

$$\frac{(0.20+x)}{(0.50-x)} = 1.20$$

whence  $x = 0.18$

at equilibrium,

$$n(\text{CO}_2) = n(\text{H}_2) = 0.32 \text{ and } n(\text{CO}) = n(\text{H}_2\text{O}) = 0.38$$

## Question 4

The first part of this question tested knowledge of some important organic reactions which are the foundation of the organic chemistry covered at AS Level. Many candidates gave good answers but there was a large number who were unable to work through the sequence without making errors. Examiners felt that many candidates had not learned the relevant chemistry.

Part (a) was in general well answered. The last two parts of the question were less well done with many candidates struggling to draw clear diagrams of the stereoisomers of **B**. Details of how to draw structural and displayed formulae and optical isomers are given in **section 10.1** of the syllabus.

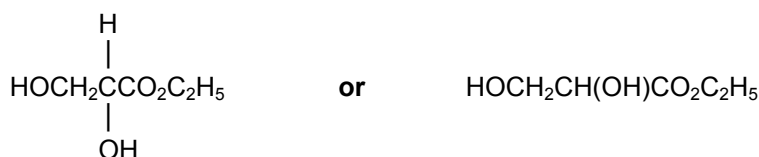
- (a) Each of the reactions involved in the sequence is listed in the relevant section of the syllabus.

Many candidates did not appreciate that when ethanal reacts with Tollens' reagent the organic product, **E**, is ethanoic acid. Incorrect answers involving compounds of silver or nitrogen were common.

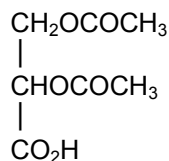
Some candidates did not realise that **C** was the diol,  $\text{HOCH}_2\text{CH}(\text{OH})\text{CO}_2\text{H}$ , which on oxidation will produce  $\text{HO}_2\text{CCOCO}_2\text{H}$ .

- (b) Compound **C** contained both an -OH group and a -CO<sub>2</sub>H group. The reactions of **C** with **D** and with **E** each produce an ester although relatively few candidates were able to draw one or both correct structures which are given below.

- (i) **C + D**



- (ii) **C + E**



In this case, candidates who drew the structure of either of the mono-esters that could be formed from **C** and **E** were given credit.

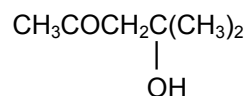
In both cases, candidates who gave incorrect structures for **C**, **D** or **E** which were alcohols or acids were given credit for answers which were esters.

- (c) Candidates who had the correct structure for **B** in **part (a)** usually scored at least two of the three marks here. The most common error was failing to draw a fully displayed structure involving the -C≡N group.

### Question 5

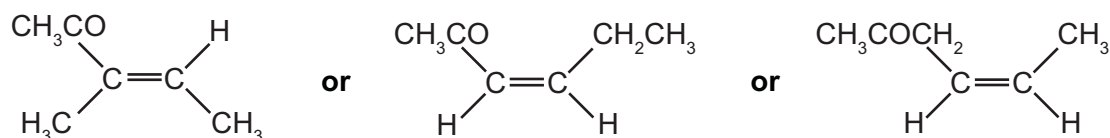
The application of chemical knowledge and understanding to unusual reactions is an important part of the study of chemistry at AS Level. Many candidates were able to answer some parts of this question but a score of more than 9 marks out of 11 was a rarity.

- (a) Very few candidates were able to deduce the structure of compound **F**. Examiners expected candidates to realise that since **G** was formed by the dehydration of **F**, the reverse process could be used to obtain the structure of **F** which is given below.



- (b) This part was well answered with many correct descriptions of the test given.
- Either alkene or ketone was acceptable, but not aldehyde. A small number of candidates gave the formula, not the name as requested, for the functional group and were penalised.
- (c) (i) Many candidates correctly deduced that step II is described as a 'dehydration' or an 'elimination'. 'Condensation' was not accepted. Those candidates who were not certain of the correct answer and gave two contradictory answers such as 'reduction or elimination' were given no credit.
- (ii) The majority of candidates correctly chose concentrated sulfuric acid as their reagent for this dehydration. 'Concentrated' had to be specified to gain the credit.
- (d) How to reduce a  $>\text{C}=\text{O}$  bond in the presence of a  $>\text{C}=\text{C}<$  bond continues to puzzle many candidates although the syllabus in **section 10.5(a)(ii)** refers to the reagent  $\text{NaBH}_4$ . Examiners also accepted  $\text{LiAlH}_4$ . The mark for the correct solvent was only awarded if the correct reducing agent was given, and for  $\text{LiAlH}_4$ . Examiners only accepted dry ethoxyethane.
- (e) Many candidates found this part difficult. Compound **G** does not exhibit *cis-trans* isomerism but was often given as one of the pair of isomers. The question asked for isomers containing the  $\text{CH}_3\text{CO}-$  group, yet many isomers offered did not contain this group.

Three pairs of isomers were acceptable as answers. The *cis* form of each is given below.





# CHEMISTRY

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<p>Paper 9701/22</p> <p>AS Structured Questions</p>
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- (a) The majority of candidates gave a correct configuration for aluminium but fewer gave a correct configuration for titanium.
- (b)(i) Examiners expected candidates to describe what happens when chlorine is passed over heated aluminium to form aluminium chloride. A surprising number used a reagent other than chlorine and many candidates made no mention of heat being necessary.
- (ii) Very few candidates were able to give a complete description of the changes that take place in this reaction.
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- (d)(i) Most candidates were able to do this calculation correctly. The most common error was to use the proton number of titanium rather than its relative atomic mass. The correct answer is given below.

$$n(\text{Ti}) = \frac{0.72}{47.9} = 0.015 \text{ moles}$$

- (ii) Fewer candidates calculated the amount, in moles, of chlorine atoms correctly. Many candidates used the relative molecular mass of chlorine rather than its relative atomic mass in their calculation. Others used the mass of titanium chloride (2.85 g) rather than subtracting the mass of titanium from this figure. The correct answer is given below.

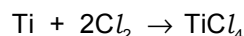
$$n(\text{Cl}) = \frac{(2.85 - 0.72)}{35.5} = 0.060 \text{ moles}$$

- (iii) Many candidates struggled with this part of the calculation. Some appeared to have decided that the correct formula of titanium chloride was  $\text{TiCl}_2$  and set out to prove it. Others struggled with some very strange ratios which should have alerted them to the fact that their calculation was probably wrong. The correct answer is given below.

$$0.015 : 0.060 = 1 : 4$$

empirical formula of **A** is  $\text{TiCl}_4$

- (iv) The equation for the formation of **A** is as follows.



- (e) The majority of candidates correctly deduced that the bonding in  $\text{TiCl}_4$  is covalent. Fewer were able to state clearly that the structure is simple molecular. Some candidates confused covalent bonds within molecules with the weak inter-molecular forces between them while others appeared to think that "tetrahedral" was an appropriate description of the structure. A small number made contradictory statements such as 'titanium chloride molecules are held together by ionic bonds' and were penalised.

## Question 2

This question tested candidates' understanding of ionisation energies and oxidation numbers, and their knowledge of the reactions of two phosphorus compounds.

Many candidates scored high marks but those who did not do so usually lost marks in **part (b)**.

- (a)(i) Most candidates gave a correct equation, the main error being to give the equation for the formation of  $\text{Ca}^{2+}$  from Ca. State symbols were less well done, with many candidates omitting them completely.
- (ii) This part was less well answered with a surprising number of candidates giving  $E^\circ$  values, despite the units for ionisation energy being given on the question paper. The other common error was to fail to include the + sign as the question required.

The correct value is  $+(590 + 1150) = +1740 \text{ kJ mol}^{-1}$ .

- (b) Examiners expect candidates to be able to describe what happens when certain prescribed reactions are carried out. The two reactions in this part are referred to in syllabus **sections 9.1(i)** and **(g)** but only a minority of candidates was able to give clear and accurate descriptions for both reactions.

Knowledge of the pH of the solution formed in each case was generally better.

- (c) (i) The majority of candidates gave a correct equation.
- (ii) While there were many candidates who correctly calculated the oxidation number of phosphorus as +5 in both compounds, a significant number gave incorrect values for one or both compounds.

### Question 3

The understanding of the principles of chemical equilibria is a key feature of the AS Level chemistry course. Many candidates showed that they could apply le Chatelier's principle correctly to an equilibrium they had not studied. On the other hand, many candidates struggled with the calculation that followed, largely because they appeared to have no systematic method of tackling the problem.

- (a) Most candidates were able to construct the balanced equation.
- (b) While there were many correct answers to this part, a significant number of candidates failed to read the question correctly and gave products that would not be formed if complete combustion had taken place, such as CO, or which were not toxic, such as CO<sub>2</sub>.
- (c) This was generally very well answered with the majority of candidates demonstrating a clear understanding of the principles involved.
- (d) (i) This was poorly answered by many candidates. The reaction to form CO to make methanol on a large scale would remove significant amounts of CO<sub>2</sub> which is associated with global warming.
- (ii) Many candidates really struggled with this calculation and a significant number gave no answer. One problem faced by many of them was how to determine the number moles of each compound present at equilibrium.

A second difficulty was that many candidates who actually attempted the calculation produced a quadratic equation which they then had to solve. The syllabus, in **section 7(f)** makes it clear that calculations of this type must be solvable without the use of a quadratic equation.

The solution is given below.

	CO <sub>2</sub>	+	H <sub>2</sub>	⇌	CO	+	H <sub>2</sub> O
initial moles	0.50		0.50		0.20		0.20
equil. moles	(0.50-x)		(0.50-x)		(0.20+x)		(0.20+x)
equil. concn.	$\frac{(0.50-x)}{1}$		$\frac{(0.50-x)}{1}$		$\frac{(0.20+x)}{1}$		$\frac{(0.20+x)}{1}$

$$K_c = \frac{[\text{CO}][\text{H}_2\text{O}]}{[\text{CO}_2][\text{H}_2]}$$

$$K_c = \frac{(0.20+x)^2}{(0.50-x)^2} = 1.44$$

taking square roots of both sides of this expression gives

$$\frac{(0.20+x)}{(0.50-x)} = 1.20$$

whence  $x = 0.18$

at equilibrium,

$$n(\text{CO}_2) = n(\text{H}_2) = 0.32 \text{ and } n(\text{CO}) = n(\text{H}_2\text{O}) = 0.38$$

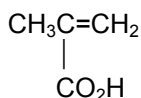
## Question 4

The first part of this question tested knowledge of some important organic reactions which are the foundation of the organic chemistry covered at AS Level. Many candidates gave good answers but there was a large number who were unable to work through the sequence without making errors. Examiners felt that many candidates had not learned the relevant chemistry.

Part (a) was in general well answered. The last two parts of the question were less well done with many candidates struggling to draw clear diagrams of the stereoisomers of **Z**. Details of how to draw structural and displayed formulae and optical isomers are given in **section 10.1** of the syllabus.

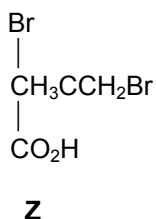
- (a) Each of the reactions involved in the reaction sequence is listed in the relevant section of the syllabus. Many candidates failed to give the correct product for the addition of HCN to propanone and this, in turn, made it very difficult for them to deduce sensible products for the subsequent reactions.

Some candidates were penalised for their structure of the compound formed from **Y**. The reaction is the dehydration of an alcohol to give an alkene and they lost marks for failing to show the double bond clearly in the following compound

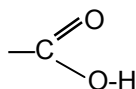


Many candidates altered their original structures but, instead of re-drawing them elsewhere on the page, they tried to amend the original. In some cases this resulted in an illegible structure for which no credit could be given.

- (b)(i) Many candidates gave a compound with two methyl groups attached to the central carbon atom as their answer to this part. The correct answer is compound **Z**, the structure of which is given below.

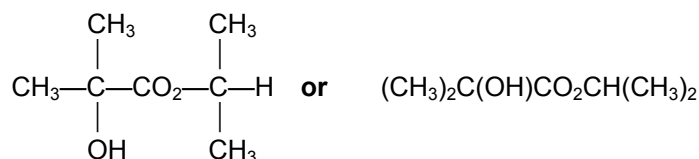


- (ii) While there were many correct answers to this part, there was a significant number of candidates who were penalised for failing to draw a fully displayed structure, the error usually being in their representation of the carboxyl group which should be drawn as shown below.



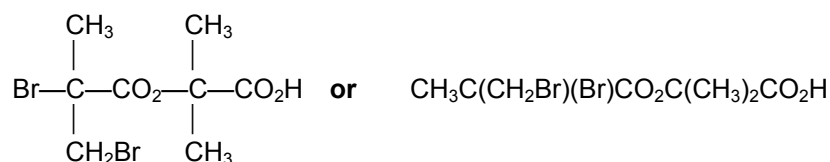
- (c) Compound **Y** contained both an -OH group and a -CO<sub>2</sub>H group. The reactions with **V** and with **Z** each produced an ester, although relatively few candidates were able to give one or both of the correct structures which are given below.

- (i) **Y + V**



Candidates who gave an incorrect structure for **Y** or **V** which could produce an ester were given credit.

- (ii) **Y + Z**

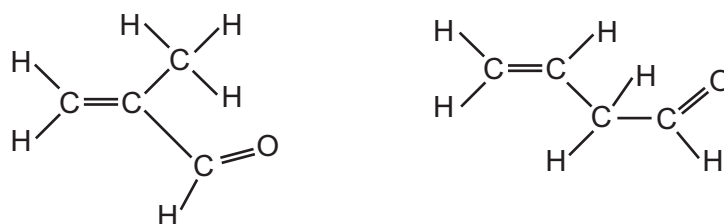


Candidates who gave an incorrect structure for **Y** or **Z** which could produce an ester were given credit.

### Question 5

The application of chemical knowledge and understanding to unusual reactions is an important part of the study of chemistry at AS Level. Many candidates were able to answer some parts of this question but few scored full marks.

- (a) Very few candidates were able to deduce the structure of compound **T**. Examiners expected candidates to realise that since **U** was formed by the dehydration of **T**, the reverse process could be used theoretically in order to obtain the structure of **T** which is  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CHO}$ .
- (b) This question was generally well answered with many correct descriptions of the test given. Candidates were asked to ‘..name **one** functional group present in **U**..’ While many chose either ‘alkene’ or ‘aldehyde’, there was a small number who gave the formula of the functional group instead and were penalised.
- (c) (i) Many candidates correctly deduced that step II is described as a ‘dehydration’ or an ‘elimination’. Those candidates who were not certain of the correct answer and gave two contradictory answers, such as ‘reduction or elimination’, were given no credit.
- (ii) The majority of candidates correctly chose concentrated sulfuric acid as their reagent for this dehydration. ‘Concentrated’ had to be specified to gain the credit.
- (d) How to reduce a  $>\text{C}=\text{O}$  bond in the presence of a  $>\text{C}=\text{C}<$  bond continues to puzzle many candidates although the syllabus, in **section 10.5(a)(ii)** refers to the reagent,  $\text{NaBH}_4$ . Examiners also accepted  $\text{LiAlH}_4$ . The mark for the correct solvent was only awarded if the correct reducing agent was given and, for  $\text{LiAlH}_4$ , examiners only accepted dry ethoxyethane.
- (e) Most candidates found **part (e)** hard, some confusing stereoisomerism, in the form of *cis-trans* isomerism, with structural isomerism. In order for the compound to contain both a  $>\text{C}=\text{O}$  group and a  $>\text{C}=\text{C}<$  bond, there are only two structures possible and these are given below.



- (f) Only a very small number of candidates was able to deduce the structure of **S**. Few realised that **S** must contain an aldehyde group, a carboxylic acid being a popular wrong answer.

**S** is  $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CHO}$ .

# CHEMISTRY

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Paper 9701/31

Advanced Practical Skills 1

## General comments

The Examiners again thank Supervisors at Centres who supplied, as requested, experimental data for **Questions 1** and **2** 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 results. Regrettably a number of Centres continue to provide no Supervisor information.

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

Some other Centres do provide Supervisor data for multiple sessions/laboratories without seating plans or candidate lists and there is insufficient data to place candidates within each session and candidates may again be disadvantaged.

## Comments on specific questions

### Question 1

The Examiners were disappointed with the general standard of titration in this question. As the titration of liberated iodine in the presence of an off-white precipitate of copper(I) iodide was considered to be more demanding than many other titration exercises, the Examiners widened the tolerance to  $0.30 \text{ cm}^3$  and  $0.50 \text{ cm}^3$  for the quality marks **(a)(v)(vi)**. In many Centres titration values varied widely throughout the Centre and few marks were awarded against the Supervisor. In such Centres there was often no consistent titre value in the candidates' results so no alternative "standard" could be obtained.

- (a) (i)** Candidates should be reminded to read the question carefully. When diluting **FA 2**, candidates were asked to record their burette readings **and** the volume of **FA 2** added to the graduated flask. Many candidates gave only burette readings or gave only the volume of **FA 2** added. Examiners expected to see the volume added recorded even when the initial burette reading is  $0.00 \text{ cm}^3$ .
- (ii)** Candidates should take care that all accurate burette readings are shown to the nearest  $0.05 \text{ cm}^3$ . This applies to an initial burette reading of  $0.00 \text{ cm}^3$  as it indicates the precision of reading the burette.
- (iii)** Most candidates diluted the appropriate amount of **FA 2** and obtained two titres within  $0.20 \text{ cm}^3$ .
- (iv)** Candidates who were well practised in titration work had no difficulty in obtaining two titres within  $0.10 \text{ cm}^3$ .

A significant number of weaker candidates recorded each titre with no decimal places, i.e. each titre apparently involved a whole number of cubic centimetres, often one or two  $\text{cm}^3$  apart.

- (v) The Examiners selected the best titre value from the Supervisor results and scaled this titre as if  $47.25 \text{ cm}^3$  of **FA 2** had been diluted. A “best” titre was similarly selected and scaled for each candidate and the scaled value compared with that for the Supervisor. Points (v) and (vi) were awarded for a difference up to  $0.30 \text{ cm}^3$  and point (vi) only for a difference of  $0.30 + \text{cm}^3$  to  $0.50 \text{ cm}^3$ .
- (b) Most candidates obtained a suitable average titre from their titration results but some failed to show how they obtained this average. Candidates are reminded that the average should reflect the precision (number of decimal places) of their individual titrations.
- (c) **Calculations**  
(i) - (iii)
- Most candidates correctly calculated the moles of sodium thiosulfate run from the burette into the conical flask.
- Most candidates were also able to use the half-equations to obtain the correct ratios although inversion of one ratio was a fairly common error (which was carried forward and not penalised in subsequent steps).
- The Examiners were very surprised to see a large number of candidates multiplying the answer to step 3 by  $\frac{1000}{250}$  rather than by  $\frac{1000}{25}$  when calculating the concentration of  $\text{Cu}^{2+}$  in **FA 3**. Another common error, in step 4 of the calculation – the concentration of  $\text{Cu}^{2+}$  in **FA 2** – was to use answer to step 3 again and multiply by  $\frac{1000}{\text{volume of FA 2 diluted}}$ .
- (iv) Most candidates showed working in each step of the calculation.
- (v) Many candidates displayed considerable variance in the significant figures quoted in each final answer. The Examiners were looking for 3 to 4 significant figures in the answer to each step. It was not uncommon to see answers to some steps given to 5 significant figures while answers to other steps were given to only two significant figures or even to one significant figure. Candidates should appreciate that working with one or two significant figures does not display the precision possible from a titration.
- (d) Most candidates simply referred to doubling the individual error, taking no account of positive or negative errors. The Examiners were looking for an explanation of errors in opposite directions – one reading too high, the other too low.
- (e) Candidates who failed to gain this mark either used  $0.05 \text{ cm}^3$  rather than  $0.10 \text{ cm}^3$  as the error or gave a final answer to only 1 decimal place.

## Question 2

- (a) (i) Most candidates presented their results in a suitable table but many failed to include a column for the rate of reaction ( $\frac{1}{\text{time}}$ ). A number of candidates omitted a column for the volume of water.
- (ii) Most candidates incorporated their results in a single table – a table with no repetition of column headings.
- (iii) Many candidates were careless in the use of units. The practical section of the syllabus describes in some detail the acceptable forms for displaying units. No unit given for the rate of reaction column ( $\text{s}^{-1}$ ) was a common error in this section.
- (iv) Many candidates failed to record the time of reaction to the nearest second – as instructed in the question. Times were regularly given to 2 decimal places (clock/watch display?) or even written in display form; minutes : seconds : hundredths of seconds.

Candidates should appreciate that a time of  $25.0 \text{ s}$  is not a time to the nearest second but indicates a precision of  $0.1 \text{ s}$  when making the measurement. In assessing the Quality marks, candidate times were rounded to the nearest second.

- (v)  $V_t$  values were calculated for 50 cm<sup>3</sup> of **FA 1** and for 25 cm<sup>3</sup> of **FA 1**. The difference between these values was expressed as a percentage of the larger of the two values and quality marks for consistency of working awarded. Points (v) and (vi) were awarded for a difference within 5% and point (vi) only for a difference of 5+% to 10%.

Well practised candidates had little difficulty in obtaining both of these marks.

- (vii) The average of the Supervisor  $V_t$  was used as a second standard.

It was disappointing to note that a significant number of Supervisors failed to obtain two  $V_t$  values that were within 5% or even 10% of each other.

The Supervisor standard was compared to the closer of the candidate  $V_t$  values and the difference calculated as a % of the Supervisor standard. Marks were awarded as above but the % differences this time were 10% for points (vii) and (viii) and 20% for point (viii).

This was a wide tolerance and most candidates scored at least one mark.

- (xi) This mark was awarded to candidates who selected appropriate volumes of **FA 1** and water for an additional experiment. Appropriate volumes of **FA 1** were in the range (10-15) cm<sup>3</sup> or (35-40) cm<sup>3</sup>.

- (b) The Examiners were looking for use of the individual volumes of **FA 1** and the total volume in the experiment (50 or 55 cm<sup>3</sup>). Many candidates simply calculated the moles of thiosulfate used in each experiment and did not refer to the significance of the constant total volume.

- (c) It was disappointing to see the number of candidates who referred to their experimental results in this section. The Examiners were simply looking for the inverse relationship between rate and time;  $\text{rate} \propto \frac{1}{\text{time}}$ . Candidates stating that  $\text{rate} = \frac{1}{\text{time}}$  were allowed this mark. A small number of candidates considered rate to be directly proportional to time.

- (d) The Examiners were surprised by the lack of quantitative statements as it was expected that candidates would be familiar with this experiment, probably from IGCSE, and would realise that a constant  $V_t$  value indicates that the rate of reaction is directly proportional to the concentration of **FA 1**.

One mark was given for correct calculation of the  $V_t$  values or for an appropriate qualitative statement.

- (e) The Examiners placed emphasis on the changes to experimental method in this section. Candidates were expected to say that the volumes of **FA 1** and water would remain constant and the experiment would be conducted at different temperatures – explaining how they would obtain these different temperatures, e.g. by water bath at set temperatures. A relatively small number of candidates gained this mark.

### Question 3

- (a) Most candidates recorded the correct observations with aqueous sodium hydroxide and with aqueous ammonia. Candidates should be discouraged from describing white solutions – white solutions do not exist, only suspensions of white precipitates or emulsions (e.g. milk). The qualitative analysis notes printed in the paper give a good indication of the type of observation expected – the initial observation and the observation in an excess of the reagent. Many candidates did not give two possible ions in the second line of the conclusion, others gave two ions on the first line and the single ion on the second line.
- (b) This was a straight forward test on the four solutions that was very badly conducted. Most candidates mentioned sodium hydroxide and aluminium (but some omitted one or other of these reagents). There was often reference to red litmus turning blue but no reference to a gas evolved in the experiment turning the litmus blue in colour. The sodium hydroxide present would also have turned the litmus blue if it had been put into the solution. Where candidates reported litmus turning blue with all four solutions the Examiners suspect that this mistake had been made. Few candidates observed the change in litmus with **FA 6** and **FA 7**. The conclusion was allowed from red litmus turning blue or reference to ammonia gas (with no test on the gas) with **FA 6** and **FA 7**.



- (c) (i) The majority of candidates observed a change in the solution from yellow to orange with **FA 5** (a few incorrectly reported formation of a precipitate) and a white precipitate with **FA 7**.
- (ii) A brown gas was often missed with **FA 6**. Some candidates had also used HCl in (b) and obtained different results to the tests in (c), including the evolution of a brown gas – which in some cases was due to heating the solution in (b).
- (iii) Most candidates correctly identified the chromate ion in **FA 5**.

Candidates often succeeded in identifying one further ion but failed to identify the **two** additional ions required for the award of **point (iv)**. The significance of the white precipitate with **FA 7** in differentiating between lead and aluminium ions was often overlooked. Some candidates who had correctly identified **FA 6** and **FA 7** as the solutions containing the nitrate or nitrite ions were able to differentiate between them from the reaction with HCl.

Some candidates tried to use the results of test (d) in identifying ions here. No credit was given here, as test (d) was a confirmatory test.

- (d) Most candidates obtained the mark for the yellow precipitate. Those who had already identified chromate and lead ions in **FA 5** and **FA 7** generally scored the second mark.

# CHEMISTRY

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Paper 9701/32

Advanced Practical Skills 2

## General comments

The Examiners again thank Supervisors at Centres who supplied, as requested, experimental data for **Questions 1 and 2** 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 results. Regrettably a number of Centres continue to provide no Supervisor information.

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

Some other Centres do provide Supervisor data for multiple sessions/laboratories without seating plans or candidate lists and there is insufficient data to place candidates within each session and candidates may again be disadvantaged.

## Comments on specific questions

### Question 1

The Examiners were disappointed with the general standard of titration in this question. As the titration of Potassium manganate(VII) with an ethanedioate at elevated temperatures was considered to be more demanding than many other titration exercises, the Examiners widened the tolerance to 0.30 cm<sup>3</sup> and 0.50 cm<sup>3</sup> for the quality marks **(a)(v)(vi)**. In many Centres titration values varied widely throughout the Centre and few marks were awarded against the Supervisor. In such Centres there was often no consistent titre value in the candidates' results so no alternative "standard" could be obtained.

- (a) (i)** Candidates should be reminded to read the question carefully. When diluting **FB 2** candidates were asked to record their burette readings **and** the volume of **FB 2** added to the graduated flask. Many candidates gave only burette readings or gave only the volume of **FB 2** added. Examiners expected to see the volume added recorded even when the initial burette reading is 0.00 cm<sup>3</sup>.
- (ii)** Candidates should take care that all accurate burette readings are shown to the nearest 0.05 cm<sup>3</sup>. This applies to an initial burette reading of 0.00 cm<sup>3</sup> as it indicates the precision of reading the burette.
- (iii)** Most candidates diluted the appropriate amount of **FB 2** and obtained two titres within 0.20 cm<sup>3</sup>.
- (iv)** Candidates who were well practised in titration work had no difficulty in obtaining two titres within 0.10 cm<sup>3</sup>.

A significant number of weaker candidates recorded each titre with no decimal places, i.e. each titre apparently involved a whole number of cubic centimetres, often one or two cm<sup>3</sup> apart.

- (v) The Examiners selected the best titre value from the Supervisor results and scaled this titre as if  $42.75 \text{ cm}^3$  of **FB 2** had been diluted. A “best” titre was similarly selected and scaled for each candidate and the scaled value compared with that for the Supervisor. Points (v) and (vi) were awarded for a difference up to  $0.30 \text{ cm}^3$  and point (vi) only for a difference of  $0.30 + \text{cm}^3$  to  $0.50 \text{ cm}^3$ .
- (b) Most candidates obtained a suitable average titre from their titration results but some failed to show how they obtained this average. Candidates are reminded that the average should reflect the precision (number of decimal places) of their individual titrations.

(c) **Calculations**  
(i) - (iii)

Most candidates correctly calculated the moles of potassium manganate(VII) run from the burette into the conical flask.

Many candidates were not able to balance the half-equations and of those who did correctly select 5 electrons in the first equation and 2 electrons in the second equation many then used a completely different ratio in the third step of the calculation. The Examiners were very surprised to see a large number of candidates multiplying the answer to step 3 by  $^{1000}/_{250}$  rather than by  $^{1000}/_{25}$  when calculating the concentration of  $\text{C}_2\text{O}_4^{2-}$  in **FB 3**. Another common error, in step 5 of the calculation – the concentration of  $\text{C}_2\text{O}_4^{2-}$  in **FB 2** – was to use the answer to step 3 again and multiply by  $^{1000}/_{\text{volume of FB 2 diluted}}$ .

- (iv) Most candidates showed working in each step of the calculation.
- (v) Many candidates displayed considerable variance in the significant figures quoted in each final answer. The Examiners were looking for 3 to 4 significant figures in the answer to each step. It was not uncommon to see answers to some steps given to 5 significant figures while answers to other steps were given to only two significant figures or even to one significant figure.

Candidates should appreciate that working with one or two significant figures does not display the precision possible from a titration.

**Question 2**

- (a) The majority of candidates recorded, in a table, the two balance readings and the two thermometer readings but a significant number failed to record the mass of **FB 4** added and the temperature change.
- (b) The Examiners corrected any incorrect subtractions and calculated  $\frac{\text{temperature rise}}{\text{mass of FB 4 added}}$  for both Supervisor and candidate. Quality marks were awarded on the difference between Supervisor and candidate values. Many candidates scored at least 1 mark for a difference of  $0.1 + ^\circ\text{C}$  to  $0.3 ^\circ\text{C}$ .
- (c) No mark was allocated to the evaluation of the “given” expression.
- (d) Most candidates were able to calculate  $12.6 \text{ g}$ , the mass of  $\text{NaHCO}_3$  reacting with  $50 \text{ cm}^3$  of  $3.0 \text{ mol dm}^{-3}$  hydrochloric acid.
- (e) Most candidates were able to add the two errors of  $0.5 ^\circ\text{C}$  but many then gave the sum as  $1 ^\circ\text{C}$  rather than as  $1.0 ^\circ\text{C}$ .
- (f) Most candidates were able to calculate  $\frac{\text{answer to (e)}}{1.50}$  but a significant number incorrectly rounded their answers; e.g.  $66.6666\dots$  was rounded to  $66.6 \%$  rather than  $66.7 \%$ .
- (g) This section of the question was not read carefully as the mass selected should have given an appropriate, measurable, temperature fall; with minimum % error in temperature measurement; and with the hydrochloric acid in excess.

Following on from the error calculation in (f) it was expected that candidates would select as large a mass as possible, but keeping the acid in excess. Most candidates who had calculated 12.6 g in (d) gave that mass again in this section. The Examiners were looking for a mass just under the mass calculated in (d) to give the maximum temperature change with the acid remaining just in excess.

- (h) One mark was awarded here for consistent recording of the balance readings in (a) and (h), i.e. recording the balance readings with consistent precision. Most candidates were awarded this mark. Consistency in recording thermometer readings was much less satisfactory. Many candidates recorded all temperature readings to the nearest 0.5 °C in (a) but only to whole degrees in (h). Some candidates claim to be able to read a thermometer graduated at 1 °C to 0.1 °C. Centres are reminded that the “general rule” in reading any instrument is to read the scale to the nearest half of a smallest scale division
- (i) One mark was given for weighing close to the mass stated in (g). Two marks were given for a comparison of the  $\frac{\text{temperature fall}}{\text{mass of FB 5 added}}$  with a fixed standard of 1.30 °C g<sup>-1</sup>. Two marks for a difference to 0.20 °C g<sup>-1</sup> and one mark for a difference of (0.20+ to 0.40) °C g<sup>-1</sup>.
- (j) No mark was allocated to the evaluation of the “given” expression.
- (k) Many candidates left this section blank, others who derived a correct equation often failed to evaluate correctly through sign errors.
- (l) The Examiners were looking for a modification to the experimental method – a description of how the apparatus would be better insulated not just the use of more insulation.

### Question 3

- (a) No observation was expected while preparing the solutions.
- (b) Where candidates selected an appropriate pair of reagents (silver nitrate followed by aqueous ammonia **or** silver nitrate and lead nitrate, each added to a fresh sample of solution) it was usual to award all of the four marks in the section.
- (c) This was an exercise in careful observation as the concentrated sulfuric acid was added to the two solid salts.

With **FB 6** (the bromide) four marking points were identified – two being needed for award of the mark. Many candidates recorded only one of these marking points.

With **FB 7** (the iodide) four marking points were identified – three being needed for award of the mark. Many candidates recorded only two of these marking points.

FB 6		FB 7	
(i)	yellow/orange/red solid, solution, liquid or mixture (not colour alone) <b>or</b> orange/red/brown gas or vapour	(i)	brown/grey/black (not blue-black) solid <b>or</b> purple gas/vapour (gas can be awarded in either of the first two boxes)
(ii)	white or steamy fumes (in either of the first two boxes)	(ii)	“bad-egg” smell or (smell of) H <sub>2</sub> S <b>or</b> test for H <sub>2</sub> S (including dichromate turning green)
(iii)	positive test for SO <sub>2</sub>	(iii)	Orange/dark red/red-brown/brown solution (no solid) on adding distilled water
(iv)	no change (but not no ppt) with starch	(iv)	blue/blue-black/ purple/purple-black/ black colour (of solution or solid)

- (d) Many candidates failed to notice any change in the colour of the solution on adding aqueous bromine. Some candidates who did see the formation of iodine in the solution then failed to see any change when starch solution was added.
  
- (e) This section was often left blank but some candidates attempted very involved explanations of their observations. Some novel chemistry was seen from time to time. Candidates often muddled the reactions involved in the two sections of the question. The Examiners were looking for the oxidation of bromide/iodide or the formation of bromine/iodine when sulfuric acid was added and that sulfuric acid was the oxidant/oxidising agent (or equivalent statement). In the second section, displacement of iodine by bromine, or bromine oxidising iodides to iodine would have gained the mark. Iodide displaced by bromine was, however, not allowed.
  
- (f) This was a straightforward part of the question and many candidates scored both observation marks and the associated deduction mark.

# CHEMISTRY

Paper 9701/04 <b>A2 Structured Questions</b>
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## General comments

The paper proved to be even better at discriminating between the good and the less good candidates than last years' with marks covering almost the full range. It was felt, however, that the overall standard was possibly a little better than in previous years. There were no indications that candidates did not have enough time to complete the paper. Several questions demonstrated a lack of knowledge by the candidates: the reactions of halides with  $\text{H}_2\text{SO}_4$ , organic reactions, and partition coefficients.

Teachers and candidates are reminded that this paper is set on the **whole** A level syllabus – not just those learning outcomes printed in bold type in the syllabus document. Although **most** marks will be allocated to the “non-AS” sections, this does not mean that **all** marks will be so allocated.

## Comments on specific questions

### Section A

#### Question 1

- (a) Most candidates correctly described acids as proton donors, and bases as proton acceptors. Some, however, incorrectly reversed the donor/acceptor roles; others stated that bases were hydroxide donors, whilst others defined Lewis, rather than Brønsted-Lowry, acids and bases.
- (b)(i) Only a minority of candidates scored [3] marks here. Although many correctly stated that chlorine atoms were electron-withdrawing, fewer stated explicitly that this caused the acids to become stronger down the table, and fewer still explained why this was the case, i.e. that the O-H bond is weakened, or the resulting anion is stabilised.
- (ii) Many candidates correctly calculated this pH as 1.94. Those who lost marks often either used the wrong  $K_a$  value from the table, or failed to take the square root.
- (iii) Few candidates scored full marks for the sketch of the titration curve. The curve should have started at pH 1.94 (or whatever pH the candidate had calculated in (ii)) – preferably labelled; taken at least three pH units to reach the end point at  $\text{vol} = 10 \text{ cm}^3$  (i.e. not horizontal, due to it being a weak acid); increased almost vertically at  $\text{vol} = 10 \text{ cm}^3$  and then levelled off at pH 12.7 (i.e. the pH of  $0.05 \text{ mol dm}^{-3} \text{ NaOH}$ : the final  $[\text{NaOH}]$  concentration after  $20 \text{ cm}^3$  had been added).
- (c)(i) Most candidates wrote a correct equation for the reaction of the anion with  $\text{H}^+$ , but fewer were able to write the equation with hydroxide,  $\text{CH}_3\text{CO}_2\text{H} + \text{OH}^- \longrightarrow \text{CH}_3\text{CO}_2^- + \text{H}_2\text{O}$ .
- (ii) This calculation of a pH of 5.07 turned out to be quite difficult for many candidates. Either they reversed the  $[\text{anion}]/[\text{acid}]$  expression, or (as in (b)(ii)) used the wrong  $K_a$  value from the table.

#### Question 2

- (a) Most candidates scored a mark for “misty fumes” and another for the equation producing  $\text{HCl}$ . Far fewer recognised that  $\text{HBr}$  would be oxidised to  $\text{Br}_2$ , and the balanced equation for the reaction producing  $\text{Br}_2 + \text{SO}_2$  was a rarity.
- (b) Most correctly quoted relevant  $E^\ominus$  values for chlorine and bromine, but only a relatively small number of candidates answered the question and *explained* how these relate to the observations.

They were expected to write something like “Br<sup>-</sup> is a stronger reducing agent (than Cl<sup>-</sup>) because its  $E^\ominus$  value is less positive”.

- (c) Almost any reducing agent with an  $E^\ominus$  lower than 1.07 V was allowed here. Exceptions were agents that included conditions that would react with Br<sub>2</sub> in a non-redox manner (e.g. OH<sup>-</sup> or NH<sub>3</sub>), and reagents that could be oxidising agents as well (e.g. H<sub>2</sub>O<sub>2</sub>). As is usually seen, several candidates (often all from the same Centre) added the two  $E^\ominus$  values rather than taking one away from the other, often due to changing the sign of one  $E^\ominus$  first, and then subtracting it. The most common correct reagents were I<sup>-</sup> ( $E_{\text{cell}} = 0.53\text{V}$ ) and SO<sub>2</sub> ( $E_{\text{cell}} = 0.90\text{V}$ ). Sn<sup>2+</sup> was also popular ( $E_{\text{cell}} = 0.92\text{V}$ )

### Question 3

- (a) The definition given in the syllabus was expected: “an element that forms ions (or compounds) with incomplete (or partially-filled) d-orbitals”. Candidates lost marks either by referring only to elements rather than ions/compounds, or not referring to d-orbitals, or stating that the orbitals were **half-filled** rather than partially filled.
- (b) Most candidates scored in (i), but in (ii) many thought that the Cu<sup>2+</sup> ion was 3d<sup>7</sup>4s<sup>2</sup>, rather than 3d<sup>9</sup>.
- (c) Many scored well here – oxidation states from +2 to +5 being the most likely.
- (d) Some candidates scored full marks here, but others knew the observations but not the explanations. The pale blue ppt. is Cu(OH)<sub>2</sub>; the resulting deep blue solution is [Cu(NH<sub>3</sub>)<sub>4</sub>]<sup>2+</sup>, formed by ligand exchange.
- (e) This caused few problems. Either VO<sub>3</sub><sup>-</sup> or VO<sub>2</sub><sup>+</sup> was accepted as the reactant.

### Question 4

- (a) (i) Various alternative spellings of homogeneous were allowed, but homozygous and homolytic, the two most common incorrect answers, were not awarded a mark.
- (ii) This turned out to be more of a discriminator than expected. Only a minority of candidates took note of the hint given in the question, and considered the species involved, and correctly related the slowness of reaction 1 to the similar (negative) charge of the reacting ions creating repulsion.
- (iii) This was very poorly answered. Most candidates drew only one hump (albeit at a lower enthalpy than the original, correctly), or two humps both starting and finishing at the same points as the original. The correct answer, given by the better candidates, showed two contiguous humps, both lower than the original, on a curve starting and finishing at the original enthalpy levels.
- (b) (i) Most scored a mark here, although some candidates thought that the oxidation of SO<sub>2</sub> to SO<sub>3</sub> would **reduce** the incidence of acid rain. Clearly these candidates had learnt that “SO<sub>2</sub> causes acid rain”, without knowing anything about the mechanism by which it causes acid rain.
- (ii) This was answered well.
- (iii) Many scored well here, writing two balanced equations, one involving SO<sub>2</sub> and NO<sub>2</sub>, and the other involving NO and O<sub>2</sub>.

### Question 5

- (a) Many scored full marks for the three formulae (of pentan-1-ol, pentan-2-ol and pentan-3-ol). The most common error was to include branched-chain alcohols.
- (b) The correct identity, of pentan-2-ol, was given by many candidates.
- (c) Many scored a mark in (i), and also in (ii), but although CHI<sub>3</sub> was the formula of choice for most candidates in (iii), some confused it with CH<sub>3</sub>I. The other product was the **anion** of the C<sub>4</sub> acid, C<sub>3</sub>H<sub>7</sub>CO<sub>2</sub><sup>-</sup>, or C<sub>3</sub>H<sub>7</sub>CO<sub>2</sub>Na. This was a much less common correct answer. Some candidates thought the product would be sodium butoxide, C<sub>4</sub>H<sub>9</sub>ONa.

- (d) This was well known by many candidates. Pentan-1-ol gives the carboxylic acid, whilst the other two alcohols give the corresponding ketones.
- (e) (i) Many scored only [1] out of [2] marks here, for not including “n” in their coefficients.
- (ii) There were many variants produced for this  $\Delta H$  value. The most common errors were not to include the C-C bonds in the calculation, or to reckon that 7 C-C bonds were formed, rather than 6, or 7 O-H bonds rather than 14, or to reverse one or more signs.
- (iii)  $\Delta H = -1000 \text{ kJ mol}^{-1}$

### Question 6

- (a) (i) This was surprisingly poorly answered by most candidates. Reagents such as  $\text{Cl}_2$  (with light, or with  $\text{AlCl}_3$ ) and  $\text{HCl}$  (without being concentrated and in the presence of  $\text{ZnCl}_2$ ) were common for **I**.  $\text{PCl}_5$  (or  $\text{PCl}_3$  with heat) or  $\text{SOCl}_2$  would have gained the mark. For reaction **II**, a similar lack of knowledge was shown. Rather than  $\text{NH}_3$ , Examiners saw  $\text{HNO}_2$  or  $\text{HNO}_3$ ,  $\text{Sn} + \text{HCl}$ ,  $\text{KCN}$  etc.
- (ii) This was better answered, the correct answer, nucleophilic substitution, being given by many.
- (iii) Many candidates were on the right lines, but their explanations were not exact or clear enough. Examiners were looking for a description that since a lone pair of electrons on  $\text{Cl}$  was delocalised over the  $\pi$  system of the benzene ring, the  $\text{C-Cl}$  bond would be stronger, and thus less easy to break.
- (b) (i) Most candidates scored a mark for  $\text{HNO}_3 + \text{H}_2\text{SO}_4$  for reaction **III**, but fewer stated that both acids had to be concentrated, and the reaction had to be carried out at  $55^\circ\text{C}$ . Likewise, some lost a mark for not stating that the  $\text{HCl}$  used with  $\text{Sn}$  in reaction **IV** had to be concentrated.
- (ii) Most candidates scored at least [1] mark here, for either *electrophilic substitution* or for *reduction*.
- (c) Only two reagents were suitable:  $\text{Br}_2(\text{aq})$  or Universal Indicator solution. The former gives a white ppt. with phenylamine but none with hexylamine; the latter turns blue with hexylamine, but stays green with phenylamine. A significant number of candidates knew these tests.
- (d) Answers to this part were disappointing. Structural formulae should **include all multiple bonds**. Thus candidates lost marks for not showing the triple bond in **D**, or the  $\text{N=N}$  double bond (NOT triple) in **E**. Candidates were also expected to know the 4-orientation with respect to  $\text{OH}$  of the incoming group in the diazo-compound.

### Question 7

- (a) Most candidates scored at least [2] marks here, for the role of iron in haemoglobin. The role of sodium in nerve cells was also fairly well known, but that of zinc was less familiar. As a cofactor to carboxypeptidase, or alcohol dehydrogenase, or carbonic anhydrase, was accepted for [2] marks from a goodly proportion of more able candidates.
- (b) Surprisingly, few scored a mark in (i). The breakage of mercury thermometers proved too easy a temptation for many; a specific industry had to be mentioned for the mark, such as the mercury cell for the electrolysis of  $\text{NaCl}(\text{aq})$ , or the manufacture of batteries, or of felt, or gold extraction. Other answers could have included fungicides or timber preservation compounds. In (ii) the breakage of S-S disulfide bonds, or complexing the  $-\text{SH}$  groups of cysteines, was better known than the salt formation with  $\text{R-CO}_2\text{H}$  groups. Both were needed, with equations, for full marks.

### Question 8

- (a) (i) Many candidates' definitions were too imprecise to be awarded a mark here. Key words looked for but not often seen were **ratio** and **concentration**. As is often the case in such a definition, the use of an equation (e.g.  $K = [\text{A}]_a/[\text{A}]_b$ ) would have helped.



- (ii) + (iii) Likewise, the calculations often showed a lack of understanding of the principle of solvent extraction. Very few candidates scored [4] out of [4], but error-carried-forward marks could be awarded if the working was shown clearly.  $K_{pc} = 20$  and total extracted = 0.44 g.
- (b)(i) The two marks here were for realising that berries contain water rather than fats, and for stating that PCBs are insoluble in water. Few candidates worked through the given information logically.
- (ii) Here again, a lack of understanding of partition coefficient was demonstrated by many candidates, who wrote that the "partition coefficient is greater in fat than in water".
- (c) Many candidates showed a good understanding of 2-way chromatography, correctly predicting in (i) that there would have been four spots after the first solvent had been used, and identifying the correct spots in (ii).

### Question 9

- (a) (i) In general candidates produced good diagrams here, showing hydrogen bonds between the N-H groups of one chain and the C=O groups of the second chain. At least two such bonds, one in each direction, needed to be shown to gain the [2] marks. It was surprising, however, that so many candidates forfeited a mark by not drawing the correct structure of the second Kevlar chain: many drew the polyamide derived from 4-aminobenzoic acid instead.
- (ii) A few candidates confused bonds within the chains with bonds between the chains, and wrote "amide", or even more incorrectly, "peptide" here.
- (iii) Most candidates scored one or two marks here. The diamine and either the diacid or the diacyl chloride were required. A significant number of candidates lost marks through carelessness in their drawing of the formulae, and showed 1,3-disubstituted compounds rather than 1,4-disubstituted.
- (b)(i) The mark scheme was quite generous here, and most candidates gained a mark. Accepted answers ranged from "water-fearing" to "cannot form bonds with water". However, "insoluble" or "does not dissolve in water" did not gain a mark. (Glass being an example of a hydrophilic material that is **insoluble** in water).
- (ii) By contrast, there were few candidates who scored the full [2] marks for this part. The two concepts looked for were that the fluorine-containing groups could not form hydrogen bonds with water, but could experience van der Waals attractions with the oil molecules. Several candidates thought the fluorine atoms **would** form hydrogen bonds with water, and hence stop the water molecules from passing through.
- (iii) Examiners were surprised that so few candidates scored a mark here. Most incorrectly suggested CFCs (not polymers) or polyfluoroethene (by analogy with polychloroethene?). Teflon, PTFE or its general formula  $(C_2F_4)_n$  were all acceptable.

# CHEMISTRY

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**Paper 9701/05**

**Planning, Analysis and Evaluation**

## General comments

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

## Comments on specific questions

### **Section A**

#### **Question 1**

- (a) The majority of the candidates correctly chose the second equation. To access the second mark candidates needed to utilise the data from the table showing the ionic radii of the group I elements. The simplest acceptable comment was a comparative one indicating that the caesium ion had the largest radius with sodium also having an ionic radius greater than the lithium (i.e. the ionic radius increases down the group). As a result, this second mark was achieved much less frequently.
- (b) (i) Most candidates were able to provide one of 'amount/mass/weight/moles' of caesium nitrate for the independent variable following this with (ii) one of 'amount/mass/weight/volume/moles' of 'gas'. In the latter case, appropriate named gases were acceptable.
- (c) A very wide variety of diagrams was offered here from the extremely neat and precise to the barely recognisable. For the first mark any suitable piece of apparatus (boiling tube, conical flask, round-bottomed flask and so on...) was required. The second mark was for showing how the gas or gases were to be collected. This could have been either via a syringe or over water. To confirm the two marks a simple appropriate connecting tube was required and some form of heating. The first mark was precluded if heating via a water-bath was indicated and if an extra piece of apparatus was included the passage of the gas into the collector should have been possible. A maximum volume of 5 dm<sup>3</sup> was imposed on the collecting syringe/measuring cylinder. The third mark was for naming the gas/gases, which would be collected in the apparatus as drawn commensurate with the originally selected equation. In most cases this was oxygen alone, the only occasion when both oxygen and nitrogen dioxide would be collected was if the second equation had been selected and a gas syringe had been used (since nitrogen dioxide is soluble in water). This third mark was not dependent on either or both of the first two marks.
- (d) A large proportion of the candidates were able to correctly calculate the volume (12 dm<sup>3</sup> of oxygen in most cases) of gas.
- (e) Rather less frequently, candidates were able to co-ordinate their answer to (d) with the volume of the collector shown in the diagram or if given for the first time in this section.
- (f) The first mark here was for indicating that a known mass or weight (not amount) of the solid was used and most candidates responded correctly. The remaining two marks were awarded less frequently particularly the second one. Two actual volume readings (initial and final) were required for the second mark it being insufficient to merely state that the collecting apparatus was full initially. For the final mark a clear statement as to how the completion of the decomposition was to

be judged was needed (e.g. until there was no further volume change or the syringe stopped moving). Heating to constant mass was deemed to be inappropriate.

- (g) A statement that either 'cooling back to room temperature' or 'repeating the whole exercise' was required here. A difficult mark to access, most responses tended to involve references to apparatus errors and/or what is best described as 'human errors'.
- (h) Again both these marks were difficult to access. Correct responses centred around the gaseous hazards listed at the start of the question and the steps require to minimise the risk arising but as in (g) many comments centred around errors of various types. Exploding apparatus as a result of the gaseous evolution was a popular suggestion.

## Question 2

- (a) There was a wide variety of data columns added to the table. The two columns required in order to plot the correct graph were the given temperatures and the derived solubilities. To access the three marks for completing the table the candidates needed to have correct columns (with correct headings) for the mass of sodium iodide and the mass of water as well as the correctly derived solubilities. A frequent error was to calculate and use the mass of solution, an error resulting in an incorrect solubility but with results overall which produced graphs of a similar shape to the correct ones. Since it was unlikely that the candidates had met the concept of solubility before there was no requirement to include units in the solubility column heading and any incorrect ones were ignored.
- (b) The correct graph required the temperature to be along the x-axis with the solubility along the y-axis both axes being correctly labelled with the variable and the units and with scales such that the plotted points extended for more than half of each axis. Of the four marks available for the graph work the first two were for setting up the axes correctly, the third for correct plotting and the final mark for correctly drawing two intersecting lines. Many candidates erroneously took the drawing of two lines to be straight lines; a difficult task given the distribution of the points if plotted correctly. The correct lines intercepted only after the extrapolation of both lines. Those candidates who did not plot their concept of solubility against temperature only had access to the first two marks while those who chose to plot two masses against each other could achieve only one mark out of the four.
- (c) The correct reading of the intercept temperature was acceptable from any graphs and was generally accessed by most candidates.
- (d) Again most candidates were able to correctly identify one or more anomalous points but in many cases this was the only mark achieved. The remaining three marks were only available for those candidates who had plotted solubility against temperature. In some cases, erroneous reasoning was given for an anomaly showing an increased solubility. Instead of this resulting from incomplete evaporation, the reason given was decomposition of the solid. A lowered solubility was more often correctly interpreted although a very small number of candidates only achieved the full four marks.
- (e) The anticipated response here was that the experiment should be repeated at closer temperature intervals around the transition temperature or perhaps repeated over the full range again at closer temperature intervals.
- (f) The first mark here was only accessible to those candidates who had plotted a correct graph since any other plot produced generally a random set of points. Correct descriptions needed to include clear reference to the direction of change such as 'the solubility increases gradually or rapidly with increasing temperature'. A mere reference to change was not enough. The second mark, which was awarded independently to the first, required a statement connecting the increasing solubility with temperature to an endothermic enthalpy change.