

CHEMISTRY

Paper 9701/11
Multiple Choice 1

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

This examination paper proved challenging to many candidates. There were many excellent performances, however the mean mark was 19/40, the median mark was 18/40, and the modal mark was 15/40. This suggests the candidates found this quite a difficult paper.

Only a small number of questions were generally found to be easy, but 70% or more of candidates chose the correct responses to each of **Questions 3, 9, 12, and 23**.

A slightly greater number of questions were found to be particularly difficult, 30% or less of candidates chose the correct responses to each of **Questions 5, 6, 7, 13, 21, 29, and 35**. These questions will now be looked at in greater detail.

Question 5

25% of candidates chose the correct answer, B. The most commonly chosen answer was C, -176 kJ mol^{-1} . 52% of candidates chose this answer, which arose when -176 kJ mol^{-1} was calculated, but the candidate failed to notice that this was the enthalpy change for two moles of ICl_3 , so the correct answer was half of this.

Question 6

28% of candidates chose the correct answer, D. Choices A, B, and C were chosen by 19%, 24%, and 26% of candidates respectively, suggesting that guessing may have occurred. However over half the candidates who scored well overall, chose D, so this was probably not the case.

Question 7

18% of candidates chose the correct answer, A. The most commonly chosen answer was B, 58% of candidates chose this answer. The question was about rate of reaction, at a higher temperature the rates of both the forward reaction and the backward reaction will be increased. Candidates choosing B were probably thinking of equilibrium position, which does indeed shift left.

Question 13

28% of candidates chose the correct answer, A. The most commonly chosen answer was B, 42% of candidates chose this answer, which arose from the misconception that concentrated sulfuric acid acts as an oxidising agent with sodium chloride.

Question 21

30% of candidates chose the correct answer, C. Choices A, B, and D were chosen by 15%, 28%, and 27% respectively, suggesting that some candidates guessed.

Question 29

27% of candidates chose the correct answer, B. The most popular answer was D, chosen by 36% of candidates. It is not possible to be sure of the reason for the number of candidates choosing D. They were possibly attracted by the fact that the OH group in 2-methylpropan-2-ol is joined to a carbon atom joined to three other carbon atoms, and therefore wrongly decided that this would produce "three alkenes". It is also possible that all those candidates who did not choose B did not realise that but-2-ene has geometric isomers, so that the three alkenes of the answer are but-1-ene, *cis*but-2-ene, and *trans*but-2-ene.

Question 35

21% of candidates chose the correct answer, C. The most popular answer was A, chosen by 32% of candidates. It is clear from this that for the majority of candidates the key point was whether or not statement 1 was true, i.e., does the oxidation of CO "occur in the atmosphere"? While CO can be oxidised to CO₂ in fires or lightning strikes, this is a combustion reaction, it is not "a reaction that occurs in the atmosphere", unlike the oxidation of NO to NO₂, and the oxidation of SO₂ to SO₃, both of which do occur "in the atmosphere".

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Paper 9701/12
Multiple Choice 1

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

This examination paper provided a suitable challenge to many candidates. There were many excellent performances. The mean mark was 23/40, the median mark was 23/40, and the distribution showed two modes at marks of 19/40 and 24/40.

Eight questions were found to be easy. 70% or more of candidates chose the correct responses to each of **Questions 1, 2, 7, 13, 18, 22, 23, and 29**.

Seven questions were found to be particularly difficult. 40% or less of candidates chose the correct responses to each of **Questions 5, 6, 10, 14, 25, 27, and 35**. These questions will now be looked at in greater detail.

Question 5

40% of candidates chose the correct answer, B. The most commonly chosen incorrect answer was C, -176 kJ mol^{-1} . 43% of candidates chose this answer, which arose when -176 kJ mol^{-1} was calculated, but the candidate failed to notice that this was the enthalpy change for two moles of ICl_3 , so the correct answer was half of this.

Question 6

40% of candidates chose the correct answer, D. Choices A, B, and C were chosen by 15%, 20%, and 24% of candidates respectively, suggesting that guessing may have occurred. However well over half the candidates who scored well overall, chose D, so this was probably not the case.

Question 10

22% of candidates chose the correct answer, A. The most commonly chosen answer was B, 58% of candidates chose this answer. The question was about rate of reaction, at a higher temperature the rates of both the forward reaction and the backward reaction will be increased. Candidates choosing B were probably thinking of equilibrium position, which does indeed shift left.

Question 14

38% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, 31% of candidates chose this answer, which arose from the misconception that concentrated sulfuric acid acts as an oxidising agent with sodium chloride.

Question 25

36% of candidates chose the correct answer, C. Choices A, B, and D were chosen by 12%, 24%, and 27% respectively, suggesting that there was an element of guesswork in the answers of some candidates.

Question 27

36% of candidates chose the correct answer, B. The most popular answer was D, chosen by 37% of candidates. It is not possible to be sure of the reason for the number of candidates choosing D. They were possibly attracted by the fact that the OH group in 2-methylpropan-2-ol is joined to a carbon atom joined to three other carbon atoms, and therefore wrongly decided that this would produce "three alkenes". It is also possible that all those candidates who did not choose B did not realise that but-2-ene has geometric isomers, so that the three alkenes of the answer are but-1-ene, *cis*but-2-ene, and *trans*but-2-ene.

Question 35

Only 19% of candidates chose the correct answer, C. The most popular answers were A and B, each chosen by 34% of candidates. It is clear from the number choosing A that for many candidates the key point was whether or not statement 1 was true, i.e., does the oxidation of CO "occur in the atmosphere"? While CO can be oxidised to CO₂ in fires or lightning strikes, this is a combustion reaction, it is not "a reaction that occurs in the atmosphere", unlike the oxidation of NO to NO₂, and the oxidation of SO₂ to SO₃, both of which do occur "in the atmosphere". It is clear from the number choosing B that for many candidates the key point was whether or not statement 3 was true. Presumably they realised that SO₂ is an atmospheric pollutant oxide, but they did not appreciate that the oxidation of SO₂ to SO₃ occurs "in the atmosphere".

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Paper 9701/13
Multiple Choice 1

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

This examination paper provided a suitable challenge to many candidates. There were many excellent performances. The mean mark was 25/40, the median mark was 24/40, and the modal mark was 29/40. This value for the modal mark is perhaps a statistical anomaly resulting from the small number of candidates for this paper, but it is pleasing all the same.

Thirteen questions were found to be easy. 70% or more of candidates chose the correct responses to each of **Questions 1, 6, 9, 13, 17, 18, 22, 24, 27, 28, 35, 37, and 39**.

Eight questions were found to be particularly difficult. 50% or less of candidates chose the correct responses to each of **Questions 7, 8, 11, 21, 23, 29, 30, and 34**. These questions will now be looked at in greater detail.

Question 7

48% of candidates chose the correct answer, D. Choices A, B, and C were chosen by 14%, 10%, and 28% of candidates respectively, suggesting that guessing may have occurred. However almost 90% of the candidates who scored well overall, chose D, so this was probably not the case.

Question 8

24% of candidates chose the correct answer, A. The most commonly chosen answer was B, 59% of candidates chose this answer. The question was about rate of reaction, at a higher temperature the rates of both the forward reaction and the backward reaction will be increased. Candidates choosing B were probably thinking of equilibrium position, which does indeed shift left.

Question 11

44% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B. 31% of candidates chose this answer, which arose from the misconception that concentrated sulfuric acid acts as an oxidising agent with sodium chloride.

Question 21

44% of candidates chose the correct answer, B. 26% of candidates chose A, and 23% of candidates chose C. Candidates choosing B as the correct answer did so realising that $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}$ can be dehydrated by concentrated sulfuric acid, but $(\text{CH}_3)_3\text{CCH}_2\text{OH}$ cannot.

Question 23

36% of candidates chose the correct answer, C. Choices A, B, and D were chosen by 13%, 30%, and 22% respectively, suggesting that there may have been guessing between choices B, C, and D by some candidates.

Question 29

47% of candidates chose the correct answer, D. 25% of candidates chose A, and 21% of candidates chose B. Candidates choosing D as the correct answer did so because they realised that the rate of hydrolysis of a tertiary alkyl bromide is independent of the hydroxide ion concentration. Candidates choosing A or B did not realise that the rate of hydrolysis of a primary or secondary alkyl bromide is affected by the hydroxide ion concentration.

Question 30

22% of candidates chose the correct answer, B. The most popular answer was D, chosen by 63% of candidates. It is not possible to be sure of the reason for the number of candidates choosing D. They were possibly attracted by the fact that the OH group in 2-methylpropan-2-ol is joined to a carbon atom joined to three other carbon atoms, and therefore wrongly decided that this would produce "three alkenes". It is also possible that all those candidates who did not choose B did not realise that but-2-ene has geometric isomers, so that the three alkenes of the answer are but-1-ene, *cis*but-2-ene, and *trans*but-2-ene.

Question 34

Only 18% of candidates chose the correct answer, C. The most popular answers were A, chosen by 41% of candidates, and B, chosen by 36% of candidates. It is clear from the number choosing A that for many candidates the key point was whether or not statement 1 was true, i.e., does the oxidation of CO "occur in the atmosphere"? While CO can be oxidised to CO_2 in fires or lightning strikes, this is a combustion reaction, it is not "a reaction that occurs in the atmosphere", unlike the oxidation of NO to NO_2 , and the oxidation of SO_2 to SO_3 , both of which do occur "in the atmosphere". It is clear from the number choosing B that for many candidates the key point was whether or not statement 3 was true. Presumably they realised that SO_2 is an atmospheric pollutant oxide, but they did not appreciate that the oxidation of SO_2 to SO_3 occurs "in the atmosphere".

CHEMISTRY

<p>Paper 9701/21 AS Structured Questions 2</p>
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General comments

AS Level Chemistry requires candidates to know a certain amount of factual chemistry, to understand some basic concepts, and to be able to apply these concepts. This paper tested each of these skills and there were some pleasing answers. Examiners felt the overall standard achieved by candidates was similar to that reached last year.

For many candidates their poorest answers were to **Questions 1** and **2** where they struggled with various aspects of chemical bonding and reaction mechanisms/pathways. Examiners were pleased with the higher standards of calculations and knowledge of organic chemistry, compared to recent papers, as shown in **Questions 4** and **5**.

Examiners felt that there were many candidates who had not checked their answers before giving in their papers.

Poor handwriting continues to cause difficulties for Examiners; if an answer cannot be read, no credit can be given.

Comments on specific questions

Question 1

Understanding the effects of induced and permanent dipoles on the properties and reactions of simple molecules is an important aspect of AS Level Chemistry. There were many good answers to this question but some candidates failed to think clearly enough and their answers were not credited.

- (a) Examiners were looking for two points, chlorine having fewer electrons and therefore weaker van der Waals' forces than those in bromine. Many candidates mentioned the relative sizes of the two molecules without referring to the numbers of electrons present. Some mistakenly thought that M_r values were part of the explanation.
- (b) Many candidates answered this part in terms of the bond strengths within the CO and N₂ molecules rather than the forces that exist between them. Those candidates who mentioned the polarity of CO molecules often failed to discuss the relative strengths of induced and permanent dipoles and received little credit.
- (c) This was generally well answered although some candidates ringed four electrons, not a pair, particularly in (ii).
- (d) Many candidates did not read this part of the question carefully. The data clearly show that bond strength is not the deciding factor. The many candidates who argued in terms of the bond energies given, clearly did not appreciate that it is the dipoles in CO and HCN that cause the reactivity of these species.

- (e) (i) Many otherwise correct answers were not credited as the $\text{C}\equiv\text{N}$ bond was not fully displayed showing a triple bond.
- (ii) Many candidates gave 'addition' as their answer and received no credit because Examiners required 'nucleophilic addition' to score the mark.
- (iii) This mechanism is clearly listed in **section 10.5(b)** of the syllabus. Despite this, there were some very poor answers. However, better candidates scored well in this part with the most common errors being to show the attack on the carbonyl carbon atom from the N of the CN^- and omitting the CN^- which is regenerated in the last step.

Question 2

The use of catalysts is an important aspect of modern industrial chemistry and candidates are expected to have a simple understanding of activation energy and how the use of a catalyst affects it. There were many sound answers to the first three parts of the question but relatively few candidates gave a fully correct answer to (d).

- (a) (i) There were many correct curves representing the distribution at the higher temperature although Examiners were surprised at the number of curves with a maximum higher than that on the original curve.
- (ii) This part was less well answered with many candidates not knowing that E_a does not change with temperature.
- (b) The majority of candidates scored two marks here.
- (c) (i) A surprising number of candidates did not know the conditions of this very important industrial process. Those who did not give the units for pressure or temperature were not credited.
- (ii) Most candidates knew that E_a is reduced for a catalysed reaction.
- (iii) Many candidates repeated their answer to (ii) and so did not receive any credit. Examiners were looking for the effect of the catalyst in providing an alternative reaction route/pathway or causing more molecules to have energy $> E_a$.
- (d) Although much of the question is about activation energy, only the better candidates stated that **reaction 1** has a high activation energy while **reaction 2** has a low activation energy. Few candidates went on to say that **reaction 1** requires energy to break covalent bonds while **reaction 2**, which involves anions and cations, requires no such energy.

Question 3

This question tested candidates' knowledge and understanding of the important reactions of a small number of elements. There were many good answers but only a very small number of candidates scored full marks.

Some answers suggested that candidates had neither carried out some of the simple reactions involved nor seen them performed.

A small number of candidates failed to give their answers as symbols or formulae, as the question required, and were not credited.

- (a) The early parts were generally well answered but (iv) and (v) caused problems for many candidates. Common wrong answers were to give a metal in (iv) and a non-metal in (v).
- (b) (i) This was usually correctly answered but some candidates gave FO_2 rather than F_2O as their answer.
- (ii) This was also well answered by many candidates although some candidates offered oxides of two different elements despite the question asking for two oxides formed by the same element.

- (c) Parts (i) and (ii) were well answered. In (iii), however, only the very best candidates gained any credit for realising that the larger iodine atom could pack 7 fluorine atoms round it, but the chlorine atom was too small to do this. Most candidates offered answers relating to bond formation or oxidising power of halogens.

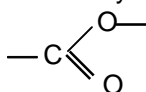
Question 4

This question tested candidates' knowledge of fundamental organic chemistry. Examiners were pleased to see many good answers and to note the improvement in candidates' knowledge of basic organic reactions.

- (a) There were many very good answers to this part. Common errors were to draw **E** with only three carbon atoms and thinking **G** was an alcohol and not an alkene.

Not all candidates drew clear structural formulae and Examiners were often confronted with structures such as, for example, $\text{CH}_3\text{CHCNCH}_3$ for **D** rather than $\text{CH}_3\text{CH}(\text{CN})\text{CH}_3$. Guidance on drawing structures is given in **section 10.1** of the Syllabus.

- (b)(i) Most candidates correctly identified the functional group as an ester. Examiners did not accept the structure



because this is also present in a carboxylic acid.

- (ii) Examiners expected candidates to state clearly that the reagents should be heated with concentrated sulfuric acid. Candidates who omitted the word 'concentrated' were not credited.

Question 5

This question tested candidates' knowledge and understanding of more complex organic chemistry. Answers were generally less good with many candidates struggling with at least one part of the question.

- (a)(i) This was generally well known although some candidates wrongly confused the term 'same molecular formula' with 'they have the same elements'.
- (ii) The need for a chiral carbon atom to be present in a compound that shows stereoisomerism was well known but many candidates were less clear in describing the second feature that gives rise to stereoisomerism – the presence of a carbon-carbon double bond. Examiners did not accept 'a double bond' because this could mean a carbon-oxygen double bond as in a carbonyl compound.
- (b) This was poorly done with a significant number of candidates not knowing that the reaction would produce $\text{NaO}_2\text{CCH}(\text{OH})\text{CH}(\text{OH})\text{CO}_2\text{Na}$. Common mistakes were to produce the mono-sodium salt or to give the product of a reaction between sodium hydrogencarbonate and one of the alcohol groups.
- (c) Many candidates explained clearly that the central carbon atom of citric acid is not chiral.
- (d)(i) Most candidates coped well with this standard calculation the answer to which is given below.

$$\text{C} : \text{H} : \text{O} = \frac{35.8}{12} : \frac{4.5}{1} : \frac{59.7}{16}$$

$$\text{C} : \text{H} : \text{O} = 2.98 : 4.5 : 3.73$$

$$\text{C} : \text{H} : \text{O} = 1 : 1.5 : 1.25$$

$$\text{C} : \text{H} : \text{O} = 4 : 6 : 5$$

empirical formula of **W** is $\text{C}_4\text{H}_6\text{O}_5$

The most common error was to round up or down the ratios $2.98 : 4.5 : 3.73$ rather than divide each one by the smallest value.

(ii) Most candidates answered this correctly.

Examiners expected to see the value of M_r being worked out as $(12 \times 4 + 1 \times 6 + 16 \times 5) = 134$.

(e) (i) Examiners were pleased to see many candidates doing this calculation correctly. The answer is given below.

$$n(\text{OH}^-) = \frac{29.4 \times 1.00}{1000} = 0.0294$$

$$n(\mathbf{W}) = \frac{1.97}{134} = 0.0147$$

$$\text{no. of } -\text{CO}_2\text{H groups in one molecule of } \mathbf{W} = \frac{0.0294}{0.0147} = 2$$

(ii) Many candidates were able to draw a fully correct displayed structure for **W**.

However, some candidates were penalised for incorrectly showing the linking of an $-\text{OH}$ group to a C atom as $\text{O}-\text{H}-\text{C}$ rather than $\text{H}-\text{O}-\text{C}$. Guidance on drawing displayed formulae is given in **section 10.1** of the syllabus.

CHEMISTRY

Paper 9701/22
AS Structured Questions 2

General comments

AS Level Chemistry requires candidates to know a certain amount of factual chemistry, to understand some basic concepts, and to be able to apply these concepts. This paper tested each of these skills and there were some pleasing answers. Examiners felt the overall standard achieved by candidates was similar to that reached last year.

For many candidates their poorest answers were to **Questions 1** and **2** where they struggled with various aspects of orbitals and bonding. On the other hand, Examiners were pleased that knowledge of organic chemistry, as shown in **Questions 4** and **5**, showed an improvement compared to recent papers.

However, Examiners felt that there were many candidates who had not checked their answers before giving in their papers. This was particularly true with the calculations in **Question 4**.

Poor handwriting continues to cause difficulties for Examiners. For this paper, one answer was propanol. On occasion, it was very difficult to decide whether the candidate's answer was 'propanol' or 'propanal' or even 'propenol'. If an Examiner cannot read an answer, no credit can be given.

Comments on specific questions

Question 1

A simple understanding of the shapes of orbitals and of electronic configurations is an important aspect of AS Level Chemistry. While there were many good answers to this question, a significant number of candidates showed poor knowledge of the shapes of s and p orbitals.

- (a) (i) Many candidates scored full marks in this part. However, others failed to identify the $2p_x$, $2p_y$ and $2p_z$ orbitals and were penalised.
- (ii) The shapes and names of s and p orbitals were not well known by many candidates. Examiners accepted drawings that showed a spherical s orbital by means of a circle around the origin, and one dumb-bell shaped p orbital, although the latter had to be along an axis to gain credit.
- (iii) The majority of candidates answered this correctly.
- (b) (i) Very few candidates gave incorrect values from the *Data Booklet*.
- (ii) While there were some very clear and correct answers, too many candidates gave answers which failed to explain the difference between the two first ionisation energies they had quoted in (i). Some candidates made ambiguous statements such as '...the energy required to remove an electron from a half-filled shell is greater than that required to remove an electron from a partially filled shell'.

Examiners expected candidates to state clearly that there is a pair of electrons in the $2p_x$ orbital of oxygen, but that all three 2p orbitals of nitrogen are singly filled. They were then expected to explain that the mutual repulsion between the pair of electrons in the $2p_x$ orbital of oxygen makes it easier to remove one of them to ionise an atom of oxygen.

Question 2

Another important part of AS Level Chemistry is to know what forces exist in gases, metals, and simple inorganic and organic compounds, and to understand how these forces affect their properties. Many answers to this question showed that candidates continue to confuse the forces within molecules with those between molecules and there is also much misunderstanding over the forces present in a metal lattice.

- (a) There were many fully correct answers to this part. However, some candidates thought that copper contained atoms rather than cations while a small number of candidates thought that copper was present as an anion in the copper lattice.

Examiners accepted 'atoms' or 'molecules' for the particle present in solid argon.

- (b) This was less well answered with many candidates giving confusing and at times contradictory answers.

For copper, Examiners expected a brief description of a metal lattice in terms of delocalised electrons surrounding a lattice of copper cations. The strong metallic bonding should then have been compared to the weak van der Waals' forces present in a sample of solid argon.

A significant number of candidates thought that the bonding in copper is covalent or were not given credit for making statements such as '...forces of attraction between the Cu^{2+} cations and electrons exist, causing copper to have strong intermolecular forces...'. Examiners do not accept such contradictory answers.

- (c)(i) This was generally well answered.

- (ii) Many candidates explained that argon does not react because it has a full outer (valency) shell or a complete outer octet of electrons. Those who stated that it does not react 'because it is a noble gas' received no credit.

- (d) While many candidates explained that down the group, the van der Waals' forces would increase, fewer linked this directly to the increase in the number of electrons surrounding the atom.

A significant number of candidates incorrectly related the increase in van der Waals' forces to an increase in the size of the noble gas atoms or an increase in their M_r .

Question 3

Interpreting data such as melting points is an important skill for AS Level candidates. There were many good answers to the early parts of this question. However, a surprising number of candidates gave incorrect equations in (c).

- (a) Many candidates answered both parts correctly. Examiners accepted either 'covalent' or 'ionic' as a correct description of the bonding in Al_2O_3 . A significant number of candidates thought that Na_2O and/or MgO has a 'simple' structure rather than being giant ionic.

- (b) There were many correct answers. Examiners did not accept MgO as a correct answer.

- (c)(i) There were many wrong equations. Some contained wrong products, such as H_2 in the Na_2O reaction, while others were unbalanced. A few candidates thought SO_2 gave H_2SO_4 when dissolved in water.

Values of pH were generally within the ranges agreed by Examiners.

- (ii) This equation was also unbalanced in many answers.

- (d) There were many very good answers to this part with candidates deducing what would be present in the molten solid and hence whether it would conduct.

Examiners did not accept current being carried by electrons in molten MgO , the only particles present being ions which will travel to the electrodes. Electrons only flow in the external circuit.

A small number of candidates believed that in MgO, ions were formed by the process of melting rather than being present in the solid.

Those answers which stated that SiO₂ is a semi-conductor received no credit because this is a property of silicon.

Question 4

The calculation in this question defeated a significant number of candidates, largely because they did not approach it in a systematic manner. On the other hand, the knowledge of organic chemistry shown by candidates in the latter parts of this question was generally very good.

- (a) Many candidates coped well with this standard calculation the answer to which is given below.

$$\text{C} : \text{H} : \text{O} = \frac{48.7}{12} : \frac{8.1}{1} : \frac{43.27}{16}$$

$$\text{C} : \text{H} : \text{O} = 4.06 : 8.1 : 2.70$$

$$\text{C} : \text{H} : \text{O} = 1.5 : 3 : 1$$

$$\text{C} : \text{H} : \text{O} = 3 : 6 : 2$$

empirical formula of **E** is C₃H₆O₂

The most common error was to round off the ratios 1.5 : 3 : 1 rather than divide each one by the smallest value.

Some candidates rounded up to give the ratio 2 : 3 : 1, while others rounded down to give the ratio 1 : 3 : 1. Thus C₂H₃O or CH₃O were popular wrong answers.

Some candidates presented their answer as C_{1.5}H₃O₁ which Examiners did not accept as it does not contain a whole number ratio.

- (b)(i) This was less well done with many candidates struggling to convert 58 cm³, the volume of gas given in the question, into the correct units which are m³. A small number of candidates omitted to convert the temperature into kelvin while an even smaller number of candidates did not appear to know that the value of *R* is given in the *Data Booklet*.

The correct answer is given below.

$$M_r = \frac{mRT}{pV} = \frac{0.130 \times 8.31 \times 400}{1.00 \times 10^5 \times 58.0 \times 10^{-6}}$$

$$M_r = 74.5$$

- (ii) In this part, Examiners were looking for evidence of a calculation, as the question stated. Many candidates did not do this and were not given credit. The correct answer is given below.

$$\text{C}_3\text{H}_6\text{O}_2 = 36 + 6 + 32 = 74$$

$$n(\text{C}_3\text{H}_6\text{O}_2) = 74.5$$

$$n = 1$$

hence molecular formula of **E** is C₃H₆O₂

However, Examiners were puzzled at the large numbers of candidates who, having given C₂H₃O or CH₃O as their answer in (i), failed to realise from their correct answer in (iii) that the earlier answer was incorrect.



- (c) Many candidates struggled to draw three different structures that were esters and a significant number included **S**, often reversed, as one of their compounds.

Some candidates were penalised for drawing their structural formulae incorrectly, e.g. $\text{HCO}_2\text{CH}_2\text{CH}_3\text{CH}_2$ instead of $\text{HCO}_2\text{CH}_2\text{CH}_2\text{CH}_3$. Guidance on drawing structural and other formulae is given in **section 10.1** of the syllabus.

- (d)(i) This was generally well answered. Examiners did not accept 'acid' or 'water/ H^+ ' as being a sufficiently accurate description of a reagent.
- (ii) This too was well answered. Again, the answer 'acid' on its own was not accepted by Examiners.
- (e)(i) The majority of candidates answered this correctly. Examiners did not accept 'carbonyl' as a fully correct answer to this question. A small number of candidates gave the formula for an aldehyde and received no credit because the question specifically stated that the name was required.
- (ii) This too was very well answered by the majority of candidates.
- (iii) Most candidates gave the correct structural formula of an alcohol that could be **G**. A small number gave $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ as their answer. This was not accepted by Examiners because the maximum number of carbon atoms in the alcohol was three.
- (f) (i) Most candidates correctly identified **S** as the correct isomer.
- (ii) The majority of those who gave a correct answer to (i) explained that **S** was an ester of a secondary alcohol which could not give the reactions described in the question.

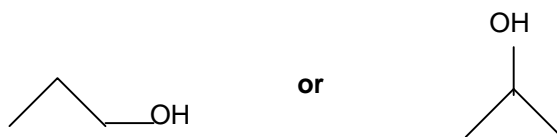
Some candidates incorrectly stated that the ester **S** was a secondary alcohol, or that the ester **S** formed a ketone on oxidation, and received no credit.

Question 5

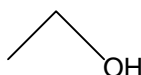
This question tested candidates' knowledge and understanding of a simple laboratory experiment to produce an alkene. Answers were generally mixed with few candidates scoring many marks in (b).

- (a) (i) Although many candidates correctly deduced that the alcohol had to be a propanol, few gave a fully correct name, i.e. propan-1-ol or propan-2-ol.
- (ii) There were relatively few candidates who drew skeletal formulae and many of those who did so gained no credit because they had not specified, in (i), which propanol they would have used in the experiment.

Correct structures are as follows.



Some candidates lost marks because their formulae did not show a definite bond to the -OH group. An example of this is shown below. This structure actually represents ethanol.



A small number of candidates drew structures which showed too many carbon atoms. Information about skeletal formulae is also given in **section 10.1** of the syllabus.

- (iii) Most candidates answered this correctly. A small number received no credit because their answers contained two contradictory types of reaction, e.g. 'elimination or condensation'.



- (b)(i)** There were relatively few correct answers to this part. Examiners expected candidates to consider what compound was being reacted and to deduce that when heated strongly the propanol could be cracked to give carbon. There were some very wild guesses at the identity of the black material, ranging from copper(II) oxide to iodine to manganese dioxide.
- (ii)** This part required candidates to think carefully about the relative pressures inside and outside the test-tube. Examiners were very pleased to see that many candidates correctly deduced that water could be sucked back into the test-tube if the delivery tube were not removed from the water before cooling is allowed to take place.
- Those candidates who thought that failure to remove the tube from the water would lead to a reaction between propene and water received no credit.
- (iii)** There were some sensible suggestions for a compound present in **X**, such as SiO_2 or Al_2O_3 .
- (iv)** This was well answered although a small number of candidates were not awarded credit for omitting to state that the sulfuric acid must be concentrated.
- (c)** This part received the most correct answers in this question. Clearly candidates felt that they were on more familiar ground and they generally demonstrated good knowledge of each of the three reactions involved.
- (d)(i)** This was relatively poorly answered with relatively few candidates knowing that poly(propene) is mainly produced by the use of high pressures. A very small number correctly stated that a Ziegler-Natta catalyst is also used.
- (ii)** This was generally well answered with many candidates appreciating that poly(propene) is not biodegradable or that its combustion products could be toxic.

CHEMISTRY

Paper 9701/23
AS Structured Questions 2

General comments

AS Level Chemistry requires candidates to know a certain amount of factual chemistry, to understand some basic concepts, and to be able to apply these concepts. This paper tested each of these skills and there were some pleasing answers with almost all candidates scoring well.

However, few candidates gave consistently good answers to all five questions. For many candidates, the poorest answers were given to **Question 4** and/or **Question 5**. Once again, Examiners feel that recent progress in this area of chemistry has not been maintained.

Examiners felt that there were many candidates who had not checked their answers before giving in their papers.

Poor handwriting continues to cause difficulties for Examiners; if an answer cannot be read, no credit can be given.

Comments on specific questions

Question 1

While a significant number of candidates gave good answers to **(c)** and **(d)**, there were many poor answers to **(a)** and to the calculation in **(b)**.

- (a)** Definitions of terms in chemical thermodynamics should be accurate and unambiguous. Relatively few candidates achieved this. The most common mistake was to fail to refer to one mole of a compound.
- (b)(i)** Many candidates produced correct answers to this question giving $\Delta H^{\circ}_{\text{reaction}} = -534.2 \text{ kJ mol}^{-1}$.
The most common error was to fail to realise that 2 mol of $\text{H}_2\text{O}(\text{g})$ are formed.
- (ii)** While there were many correct answers, some responses puzzled Examiners.
A significant number of candidates attempted to explain the lack of reaction in terms of the high bond energy of the $\text{N}\equiv\text{N}$ bond which they believed to be present in N_2H_4 . A small number thought that hydrogen bonding between the N_2H_4 molecules was so strong it inhibited the reaction.
- (iii)** This was generally well answered.
- (c)(i)** There were many good, clear diagrams in this part.
- (ii)** While many candidates did well, some failed to give a three-dimensional representation of the shape of an ammonia molecule and were not credited.
- (iii)** This was less well done with many candidates giving an incorrect bond angle, usually 120° , presumably because they had overlooked the lone pair of electrons on each of the N atoms.
- (d)** The majority of candidates correctly calculated the oxidation state to be -2.

Question 2

There were many sound answers to this question but, as with **Question 1**, the definitions in **(a)** were often ambiguous.

- (a)** Relatively few candidates were able to give a fully correct answer to this part. Many candidates made no reference to gaseous atoms or to one mole of them. Some candidates used very general phrases such as 'one mole of an element' or 'one mole of a substance'. Others made statements which suggested that they had not read carefully what they had written, such as '...the energy required to remove one electron from one mole of gaseous atoms to form a cation'.
- (b)** Both parts were well answered by the majority of candidates.
- (c)** A surprising number of candidates struggled with parts of this calculation, often because they did not set out their answer in a logical manner.
- (i)** Most candidates correctly calculated the amount, in moles, of lithium to be 0.12. Those who went wrong often used 2Li in their calculation.
- (ii)** Many candidates correctly calculated the volume of hydrogen to be 1.44 dm^3 . A small number used the volume of 1 mol of a gas as 22.4 dm^3 rather than 24 dm^3 , and were not credited because the question specifically mentioned 'room temperature and pressure'.
- (iii)** This was less well done with many candidates failing to obtain the correct answer of 0.24 mol dm^{-3} .
- (d)** While there were many correct answers to this part, there were sufficient incorrect answers to suggest that a significant number of candidates had never seen this reaction carried out.

In addition, the equation was often unbalanced with chlorine being represented as 'Cl' and sodium chloride as ' Na_2Cl ' or ' NaCl_2 '.

Question 3

This question tested candidates' knowledge and understanding of the important reactions of a small number of elements. There were many good answers but only a very small number of candidates scored full marks.

Some answers suggested that candidates had neither carried out some of the simple reactions involved nor seen them performed.

- (a) (i)** This was generally well answered but a surprising number of candidates wrongly chose potassium.
- (ii)** While there were many correct answers, Examiners were puzzled by those answers which involved oxides of transition metals rather than of carbon or sulfur.
- (iii)** This was well done by the majority of candidates.
- (iv)** A surprising number of candidates chose sodium rather than aluminium in this part.
- (v)** While there were some candidates who thought that the element concerned was sulfur, the majority correctly chose silicon.
- (vi)** This was generally well done.
- (b)** There were many good answers to this part.

- (c) A surprising number of candidates failed to read the question carefully and gave answers that did not involve the elements of Period 3, sodium to argon.
- A small number of candidates who failed to give the formulae of the oxides as the question required were not credited.
- (i) This produced many strange answers, two of the most common wrong answers being BeO and CO₂.
- (ii) This was generally well done but oxides of carbon were, once again, a common wrong answer.
- (iii) Most candidates gave Na₂O as their answer. Those who gave 'CaO' or 'NaO' received no credit.
- (iv) There were many correct answers to this part.

Question 4

Answers to this question were generally less sound than those to earlier questions, many candidates clearly struggling to deduce the correct answers.

- (a) Most candidates knew that reaction 1 was a substitution but only those who stated that it was a free radical substitution received any credit. Answers for reaction 2 were generally better.
- (b) In this part, there seemed to be much uncertainty among candidates as to what the correct answers were with only a small number of candidates giving three correct answers.
- (i) Candidates are expected to know that the reaction between CH₃COCH₃ and HCN (reaction 4) is a nucleophilic addition reaction – see syllabus **section 10.5(b)**. While many clearly did, a significant number were unable to give the product of the addition reaction.
- (ii) The mechanism of an S_N2 nucleophilic substitution is mentioned in the syllabus – in **section 10.3(b)** – but many candidates failed to identify I⁻ in reaction 3 as a leaving group.
- (iii) Few candidates realised that reactions 3 and 4 must also contain electrophiles.
- (c) This was generally well answered.
- (d) There were many correct answers to this part. The most common wrong answer was to give HCN rather than CN⁻ as the nucleophile in reaction 4. Those candidates who gave the answer 'HCN or CN⁻' received no credit; Examiners do not give marks for contradictory answers.
- (e) There were many good attempts to answer this part.

Question 5

This question tested candidates' knowledge of a number of important organic reactions. While there were many correct answers to each part, few candidates answered all parts correctly.

- (a) The syllabus, in **section 10.1**, shows candidates how to draw displayed formulae and how to represent the two isomers of a chiral compound. The majority of candidates gave two correctly drawn structures.

The most common mistake was to fail to draw the fully displayed structures of the carboxyl group although a small number of candidates failed to identify the chiral centre.

(b) This was poorly done by many candidates with incorrect reagents often being used.

In step 1, many candidates failed to state that dichromate(VI) must be in acid solution. Examiners were impressed, however, by the numbers who knew that the aldehyde formed has to be removed quickly in order to prevent further oxidation.

Many candidates gave 'HCN' rather than 'HCN in the presence of CN^- ' as their reagent in step 2.

In step 3, Examiners did not accept 'acid' as the answer; they expected candidates to identify the acid used.

In all three steps, Examiners only awarded the 'condition mark' if the reagent was correct.

(c) (i) Relatively few candidates identified dehydrogenase as a protein.

(ii) This was quite well answered although a significant number of candidates wrongly gave Tollens' or Fehling's reagents as their answer instead of 2,4-dinitrophenylhydrazine. Some candidates abbreviated the name of the latter to, for example, DTP, and were not credited.

(iii) In this part, a popular wrong answer involved reactions of the $-\text{OH}$ group in lactic acid with reagents such as PCl_5 . These candidates had clearly forgotten that the carboxylic group in both acids would also react with PCl_5 .

(iv) This was generally well answered.

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Paper 9701/31

Advanced Practical Skills 31

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, 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;
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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 but without seating plans or candidate lists and there is insufficient data to place candidates within each Session so again candidates may be disadvantaged. Where more than one Session/Laboratory is used, the candidates should be reminded to complete the boxes on the front page of their scripts with the relevant information.

It is important that any **erratum notice** is passed on to the Invigilator and, where appropriate, then to all the candidates. It was apparent that not every Centre informed the candidates of the results for the tests with 2,4-DNPH for **Question 2(g)** as provided on the **erratum** sheet supplied by CIE.

Comments on specific questions

Question 1

It was pleasing to see that the majority of candidates were able to carry out the experiment with a high degree of success. The weaker candidates usually gained at least 10/26 marks, and the better candidates gained marks in the 17-21 range. The lack of candidates gaining marks in the 22-26 range appeared to be due to problems with the graphical section, some of the calculations and the explanation of errors.

- (a) The majority of candidates set out their data in a single table with the required headings and units. Some recorded the initial temperature only once, and a few recorded only the change in temperature. There are still candidates who read thermometers calibrated to 1°C to the nearest degree rather than to the nearest 0.5°C . A few candidates recorded thermometer readings to two decimal places so lost the mark. Candidates should be advised as to the appropriate degree of precision with which to report readings taken from standard apparatus. A substantial minority of candidates omitted the two extra experiments or chose inappropriate volumes. However, the accuracy with which candidates performed the experiment was pleasing with many achieving full marks in this section.

- (b) Most candidates gained two out of the four available marks. Plotting was generally good and the axes correctly labelled. A few candidates lost the plotting mark as the maximum temperature instead of the rise in temperature was used. The marks most commonly lost were for scales which did not allow the points to be plotted over at least half the graph paper and, more commonly, for not drawing lines of best fit. Candidates should be reminded that only two points cannot lead to a best-fit line on a graph. The wording in the stem of (a) should have aided the candidates to select extra volumes which would provide them with at least three points each side of the maximum temperature rise. Some candidates lost this fourth mark by drawing a single curved line through the points.
- (c) Many candidates gained this mark. The most common error was to state the maximum temperature rise from the table of results rather than use the intercept value from the graph.
- (d) The majority of candidates were able to explain that the temperature rise was the dependent variable.
- (e) Most candidates gained the mark for writing a balanced equation for the reaction.
- (f) This part of the question was answered well by the majority of candidates. Correct working was shown in most cases. Even those who had not constructed the equation for full neutralisation were able to gain the first mark.
- (g) Fewer candidates than expected gained this mark. It was usually lost by the answer being recorded to a number of significant figures that was inconsistent with the accuracy with which the experiment could be performed.
- (h) The response to this part of the question was disappointing. Candidates should be encouraged to read through all the information given in the question and act upon it. A substantial minority ignored the prompt that separate volumes of **FA 1** and **FA 2** were mixed together, or used an incorrect value for the specific heat capacity of the solution. The most common errors in the second part of the question were failing to divide the answer by the number of moles of sulfuric acid from (e)(i) or omitting the negative sign indicating an exothermic reaction.
- (i) Better candidates were able to provide a good explanation based on the percentage errors or differences in calibration of the two items of apparatus for the first part. Weaker candidates tended simply to rephrase the question by stating that a burette is more accurate than a measuring cylinder. Fewer candidates gained the mark for the disadvantage as many concentrated on the time required to fill a burette rather than the longer time it would take for the **FA 2** to be run into the plastic cup containing **FA 1** (incurring heat energy losses).
- (j) Two different significant sources of error were needed to access the mark. Most candidates correctly gave heat energy loss but then went on to specify no lid and no extra insulation for the plastic cup. The best candidates stated either that the initial temperatures of both solutions should have been taken or that the thermometer used should be graduated at 0.5°C or 0.2°C intervals as the second source of error.
- (k) Candidates should be reminded that readings may be 'on the line' or 'between the lines', hence the maximum error is half the smallest calibration interval. Also, where two readings are taken to generate a quantity, the maximum percentage error involves the doubling of the maximum error for a single reading. Although most candidates gained the first mark, few were awarded the second.

Question 2

This question differentiated well between good and weaker candidates. The better candidates usually gained at least 9/14 marks in this question and demonstrated a good knowledge of the tests for both ionic and covalent compounds.

- (a) The majority of candidates correctly selected silver nitrate as their first reagent and many went on to gain this mark by giving (aqueous) ammonia as the reagent to add after the $\text{Ag}^+(\text{aq})$. However, a large minority lost this mark by using lead nitrate either instead of silver nitrate or in a supplementary test. While incorrect formulae for reagents was not penalised in this examination session, a few candidates only gave the formula of the ion involved in the reaction without the relevant state symbol so lost the mark. Candidates should be informed that name or formula of the reagent is expected to be given in full. Candidates should be encouraged to learn the correct formulae for the common reagents or to use the Qualitative Analysis Notes with greater thought and care as incorrect formulae are likely to be penalised.
- (b) Most candidates were able to gain the tabulation mark though a few repeated the reagents or did not make a clear separation between the two observations for the three unknowns. The observations were usually very clearly and correctly stated. The main reason for any loss of this mark was imprecision in colour of precipitate. Candidates should be encouraged to use the colours listed in the Qualitative Analysis Notes.
- (c) The vast majority of candidates gained this mark provided $\text{Ag}^+(\text{aq})$ had been used.
- (d) Many candidates were able to gain at least two out of the three marks in this section. The mark most commonly lost was the reaction of **FA 4** with the alkalis. Some also lost a mark by reporting a precipitate was formed when mixing **FA 6** with **FA 4** or **FA 5**.
- (e) A substantial number of candidates correctly reported an orange colour being formed but some omitted that it was still a solution or that no precipitate was formed.
- (f) While the majority were able to provide the identity of the ion correctly and, less frequently, the identity of the solution, only the better candidates supplied sufficient evidence for their choices. As some candidates had contradictory observations in (d) this was understandable.
- (g) The responses to this question varied considerably. Candidates from some Centres appeared conversant with the tests, successfully made Tollens' reagent, and were able to gain all three marks. Others lost marks by reporting the appearance of precipitates when acidified dichromate was used. The range of colours reported on warming the unknowns with the Tollens' solution were sometimes outside those expected.
- (h) Both marks were accessible to able candidates, and weaker ones were able to gain the second mark which was awarded for the correct observations with Tollens' solution given as evidence. As neither a tertiary alcohol nor a ketone would be oxidised by acidified dichromate it was necessary to give the result with 2,4-DNPH in the evidence for the first mark or to state that **FA 7** did not react with any of the reagents. Candidates should be reminded that a greyed-out box in a table denotes no test carried out rather than a negative result of such a test.

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Paper 9701/33

Advanced Practical Skills 31

General comments

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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 but without seating plans or candidate lists and there is insufficient data to place candidates within each Session so again candidates may be disadvantaged.

The paper generated a wide range of marks indicating that the more able candidates were able to answer the questions with ease whilst the weakest candidates found much of the paper difficult. Every mark on the paper was awarded although several of the marks were not awarded frequently. There was little evidence of candidates failing to finish the paper in the allocated time although some weaker candidates left calculation sections blank.

Comments on specific questions

Question 1

The majority of candidates successfully performed the practical work in the question, but the quality of graph plotting was disappointing.

- (a)** For the award of the first mark in this section, Examiners looked for any evidence that candidates had followed the instructions for the experiment. Temperatures of the cold water were required to be recorded at 0, 1, 2 and 3 minutes, T_1 recorded in the box and temperatures of the cooling mixture recorded every $\frac{1}{2}$ minute between 5 and 8 minutes. Evidence for this mark was sometimes seen and credited in pencil jottings against the instructions for the experiment.

The second mark was awarded for acceptable tabulation – correct headings and correct use of units. Attention is drawn to the acceptable form of units as described in the syllabus. A significant number of candidates were not awarded this mark as they recorded times such as 5.30 in a column headed time / minutes.

The final mark was awarded for recording all temperatures here and in the table in **(d)** to the nearest 0.5 °C and all balance readings in **(d)** to a consistent number of decimal places. A large number of candidates, using a thermometer graduated at 1 °C, only recorded temperatures as whole numbers. A small minority of candidates were not awarded this mark as every temperature in **(a)** was recorded to 1 decimal place – but always a zero. The Examiners consider that as out of the 12 temperatures to be recorded 7 of them referred to a gently cooling mixture, at least one reading should have been between graduations on the thermometer and recorded as .5 °C.

- (b)** Most candidates plotted temperature against time and correctly labelled the axes.

Many candidates made a very poor selection of the temperature scales – compressing all of the points into 2 or at best three “large” squares vertically. The Examiners expect, as a general rule, to see points plotted over at least half of each axis.

Points were generally plotted within the $\frac{1}{2}$ small square tolerance allowed by the Examiners. This was a very generous tolerance. It is to be noted however that many candidates did not take care when plotting points – those that should centre on a grid line were frequently off that line. Some candidates, plotting a point within $\frac{1}{2}$ a small square of its correct position, managed to plot the point on the “wrong side” of a grid line, i.e. in an incorrect small square. In this case the plotting mark was not awarded.

Some candidates did not understand the concept of extrapolating both lines to find the required temperatures at $t=4$ minutes. The majority of candidates, however, were able to do this and to read correct temperatures from the graph.

- (c)** Where values for $(T_3 - T_2)$ and $(T_1 - T_3)$ had been calculated in **(b)** most candidates were able to calculate the energy changes in the cold water and the hot water. Errors seen infrequently in this section were, use of 100 cm^3 instead of 50 cm^3 as the volume of the water; use of 4.3 J instead of the 4.2 J given in the stem of the question or failure to multiply three terms together – volume of solution or 4.2 often being omitted.

The calculation in **(iii)** was not checked as the expression had been given but answers were expected to be given to 2 or 3 significant figures

- (d)** This section caused unexpected difficulties. Experiment 1 was generally performed well but many candidates appeared to be unfamiliar with the method of weighing an empty tube, weighing into it a stated mass of solid and reweighing the tube + any residue after the solid had been tipped out of the tube. Better candidates recorded and used these masses exactly as expected. A significant number of candidates subtracted the mass of the empty tube rather than the mass of tube + residue from the mass of tube + ammonium chloride. Many of the weakest candidates recorded balance readings and masses at random in the table – some even having a mass of ammonium chloride that could not be derived from the recorded balance readings. Where Examiners were able to calculate $m/\Delta T$ for each experiment most candidates scored well in “quality” marks. Two marks were available for a comparison of the two values obtained from the candidate’s results and a further two marks for comparison of a “standard” value of 1.70 with the closer of the candidate’s values.
- (e)** This was a similar calculation to those performed in **(c)(i)** and **(ii)** but errors were seen more frequently in this section. 4.2 J was used instead of 4.3 J ; 50 cm^3 volume of water or even the mass of ammonium chloride was used or the temperature change for experiment 2 was used instead of that for experiment 1.

Part **(ii)** proved to be one of the most inaccessible marks on the paper. Many vague answers about heat loss or gain were seen. The Examiners were looking for answers connecting the temperature change in the beaker and the temperature change in the solution. Some candidates gave contradictory answers such as the beaker absorbs heat energy from the solution.

In **(iii)** most candidates added the two heat energy terms together but forgot to multiply the answer to **(c)(iii)** by the temperature change in experiment 1.

Part **(iv)** was answered correctly by nearly all candidates – it was very rare to see an incorrect relative molecular mass for ammonium chloride. Some candidates did use the mass from experiment 2 rather than the mass from experiment 1. Examiners were looking for answers to 2 or 3 significant figures.

Use of data from experiment 2 was penalised only once – the first time it was seen. Most candidates were able to perform the calculation in **(v)** but a small number used the answer to **(e)(i)** rather than the answer to **(e)(iii)** in the calculation.

Most candidates gave a +ve sign in **(v)** and correctly stated in **(vi)** that the reaction was endothermic or that the temperature had fallen during the experiment.

Most candidates were awarded the mark for showing working in their calculations and those who gave their answers in **(c)(iii)** and **(e)(iv)** to 2 or 3 significant figures were awarded the final mark in this section.

- (f)** Most candidates were able to calculate the difference between their answer to **(e)(v)** and the given book value. Where there had been an error in the experimental results or in the calculation and the difference was greater than the book value some candidates inverted the values to obtain less than 100%. Candidates were not penalised for calculating values greater than 100%.
- (g)** Two marks were available in this section. The first was a very accessible mark for stating an error such as loss or gain of heat (energy). Either was allowed, as there were two parts to the experiment, one at elevated temperatures the other at lowered temperatures.

Most candidates suggested a reasonable improvement but were unable to explain how the improvement would prevent transfer of heat energy. It was not sufficient to say "use a lid as it prevents heat loss/gain". Using a lid prevents heat transfer by convection, lagging prevents heat loss by conduction.

Question 2

- (a)** Most candidates gave a named acid and barium chloride (nitrate) as their reagents in **(i)**. A small number of candidates incorrectly reversed the position of the reagents. Others used a named acid and lead nitrate. Candidates should be aware that sulfuric acid should not be used in conjunction with barium chloride (nitrate) when testing for a sulfate. Nitric acid is the only acid that can be used successfully with lead nitrate.

Part **(ii)** was another of the infrequently awarded marks. It was clear that the majority of the candidates had not read or understood the significance of the sentence about the solubility of carbonates sulfates and nitrates. The candidates were asked to explain the order in which the reagents would be added to **FA 2**, **FA 3** and **FA 4**. From the results recorded in **(iii)** many candidates clearly added the reagents to separate samples of **FA 2**, **FA 3** and **FA 4** without making this clear in their explanation in **(ii)**. The Examiners were looking for an understanding that if the acid is added first it removes (as well as reveals) the carbonate before the addition of barium chloride (nitrate). If the acid was added after the barium chloride (nitrate) it would dissolve the barium carbonate formed.

In **(iii)** many candidates recorded gas given off when the acid was added to **FA 3** and **FA 4** but this was not considered by the Examiners to be an observation. The evolution of gas is seen as effervescence or as bubbles in the solution or is confirmed by an appropriate chemical test on the gas. Reference to limewater was often seen but the recorded observation seemed to imply that it was added to the solution. There should have been clear reference to a gas formed that turned limewater cloudy/milky etc. Where acid was added after the barium chloride (nitrate) it was common to see recorded observations for the production of gas or for the solubility of the precipitate in the acid but not for both of them.

The result of imprecise observation or of adding the reagents to fresh samples was that sulfate was often and incorrectly identified in all three solutions. Most candidates were able to correctly identify the two solutions containing the carbonate.

The most able candidates gained both marks in **(iii)** and both marks in **(iv)**.

- (b) The Examiners were disappointed with the quality of the recorded observations in this section. **FA 5** was a solution of copper(II) sulfate and as such should have given a standard set of observations as listed in the Qualitative Analysis Notes. Many candidates recorded solutions when precipitates should have formed and vice versa.

In (ii) candidates were instructed to warm the solution if no precipitate had formed with the aqueous sodium hydroxide added in (i). The majority of candidates heated all of the solutions from (i) even where a precipitate had formed. **FA 6** was the only solution that should have formed no precipitate with aqueous sodium hydroxide or with aqueous ammonia. Most candidates reported that red litmus turned blue on warming the solution but a significant number omitted to say that it was the gas evolved on heating the solution that had this effect on the litmus paper.

There was a clue in the instructions – “leave the tube to stand for 2-3 minutes” after adding aqueous sodium hydroxide or aqueous ammonia. Reference to the Analysis Notes and hopefully previous laboratory experience should have triggered thoughts of $\text{Fe}^{2+}(\text{aq})$ or of $\text{Mn}^{2+}(\text{aq})$.

FA 8 did contain the manganese ions. As usual, observations with the manganese compound were very poor – many colours were recorded that were outside the off-white to pale brown colour range allowed for the initial precipitate with aqueous sodium hydroxide or with aqueous ammonia. There was often failure to see or record any darkening to a brown colour on standing.

FA 7 contained $\text{Co}^{2+}(\text{aq})$ ions. Candidates were not asked to identify the ions present – the Examiners were looking for careful observations. The initial, and obvious, blue precipitate on adding aqueous sodium hydroxide was missed by many candidates as was the pink precipitate, mixed with the blue precipitate, to be seen on adding further sodium hydroxide.

- (c) Most candidates were able to identify the ions present and there was usually sufficient evidence in the observations to support the conclusions. In giving evidence to support the identity of the cation many candidates copied their evidence from the Qualitative Analysis Notes – even where this contradicted the recorded observations.

The Examiners would encourage candidates to describe their observations in similar terms to those used in the Qualitative Analysis Notes.



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Paper 9701/34

Advanced Practical Skills 32

General comments

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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 but without seating plans or candidate lists and there is insufficient data to place candidates within each Session so again candidates may be disadvantaged. Where more than one Session/Laboratory is used, the candidates should be reminded to complete the boxes on the front page of their scripts with the relevant information.

It is important that any **erratum notice** is passed on to the Invigilator and, where appropriate, then to all the candidates. It was apparent that not every Centre informed the candidates of the results for the tests with 2,4-DNPH for **Question 2(g)** as provided on the **erratum** sheet supplied by CIE.

Comments on specific questions

Question 1

It was pleasing to see that the majority of candidates were able to carry out the experiment with a high degree of success. The weaker candidates usually gained at least 11/26 marks, and the better candidates gained marks in the 19-22 range. The lack of candidates gaining marks in the 23-26 range appeared to be due to problems with the calculations and the explanation of errors.

- (a) The majority of candidates set out their data in a single table with the required headings and units. Some recorded the initial temperature only once, and a few recorded only the change in temperature. Almost all candidates were consistent in their display of balance readings. However, many are still only reading thermometers calibrated in 1°C to the nearest degree rather than to the nearest 0.5°C. A few recorded thermometer readings to two decimal places so lost the mark. Candidates should be advised as to the appropriate degree of precision with which to report readings taken from standard apparatus. A minority of candidates omitted the two extra experiments but the masses chosen by those who followed the instructions were generally well chosen. The accuracy with which candidates performed the experiment was pleasing with many achieving full marks in this section.



- (b) Most candidates gained two out of the four available marks. Plotting was generally good and the axes correctly labelled. A few lost the plotting mark as the minimum temperature instead of the fall in temperature was used. The marks most commonly lost were for scales which did not allow the points to be plotted over at least half the graph paper and, more commonly, for omitting the origin when drawing the line of best fit. Candidates should be reminded to read the information given in the question carefully as they were prompted, at the top of the page, to consider use of (0,0) when drawing the best-fit line.
- (c) The majority of candidates were able to explain that the mass of NaHCO_3 was the independent or controlled variable. Weaker candidates responded in terms of an easier gradient calculation.
- (d) Most candidates gained the mark for writing the equation for the reaction.
- (e) The majority of candidates drew construction lines which gave a sufficiently large triangle for obtaining the gradient, though some lines were very faint. Any incorrect reading of coordinates from the lines tended to be owing to the choice of a difficult scale when plotting the graph. The calculation of the gradient was correct from most of the candidates with very few inverting their figures.
- (f) There were fewer than expected correct responses. Although the majority calculated the M_r of NaHCO_3 correctly, only the better candidates used the gradient of the graph to calculate the theoretical fall in temperature in $^\circ\text{C mol}^{-1}$. A very few successfully used a method involving similar triangles for the calculation.
- (g) Few candidates gained both of these marks though more accessed the first mark than the second. The most common error in the first part was to use the M_r calculated in (f) rather than the volume of solution as indicated in the information given with the value for the specific heat capacity to be used. Better candidates were able to gain this mark. The second mark was usually lost by either omission of the correct sign or by recording the answer to a number of significant figures that was inconsistent with the accuracy with which the experiment could be performed.
- (h) Many of the answers involved the use of a lid or increased insulation of the plastic cup. However, both were needed. A substantial number of candidates lost the mark by stating that these were required to prevent heat loss from the solution. This is not relevant in an endothermic reaction. The better candidates wrote about preventing the transfer of heat from the surroundings.
- (i) Only better candidates were able to provide an explanation based on the percentage errors or differences in calibration of the two items of apparatus. Weaker candidates tended to simply reiterate the question by stating that a burette is more accurate than a measuring cylinder.
- (j) Candidates should be reminded that readings may be 'on the line' or 'between the lines', hence the maximum error is half the smallest calibration interval. Also, where two readings are taken to generate a quantity, the maximum percentage error involves the doubling of the maximum error for a single reading.
- (k) Some Centres appeared to have dealt with types of error better than others. The most common mistakes were 'parallax error', and stating that 'the temperature should fall' indicating that the change of reagent had not been noticed.

Question 2

This question differentiated well between the good and weaker candidates. The better candidates usually gained over 9/14 marks in this question and demonstrated a good knowledge of the tests for both ionic and covalent compounds.

- (a) The majority of candidates correctly selected barium chloride (or barium nitrate) as their first reagent and many went on to gain this mark by giving hydrochloric or nitric acid as the reagent to add after the $\text{Ba}^{2+}(\text{aq})$. However, a large minority lost this mark by adding sulfuric acid or by using lead nitrate in a separate test. Whilst incorrect formulae for reagents was not penalised in this examination session a few candidates only gave the formula of the ion involved in the reaction without the relevant state symbol so lost the mark. Candidates should be informed that name or formula of the reagent is expected to be given in full. Candidates should be encouraged to learn the correct formulae for the common reagents or to use the Qualitative Analysis Notes with greater thought and care as incorrect formulae are likely to be penalised.
- (b) Most candidates were able to gain the tabulation mark though a few repeated the reagents or did not make a clear separation between the two observations for each unknown. The observations were usually very clearly and correctly stated, and the most common reason for losing this mark was the use of sulfuric acid.
- (c) The majority of candidates gained this mark provided $\text{Ba}^{2+}(\text{aq})$ had been used. A few lost the mark by omitting that the precipitate remained when an appropriate acid was added (hence ruling out carbonate and sulphite).
- (d) Many candidates were able to gain at least two out of the three marks in this question. The mark most commonly lost was in warming the mixture with sodium hydroxide. Even when red litmus was reported turning blue a surprising number omitted to state that it was a gas having this effect. The next most common error was the reporting of a grey-green or a blue-green precipitate with **FB 7** and one or both of the alkalis.
- (e) A substantial number of candidates reported the green precipitate turning brown either here or in (d). A few lost the mark by stating that the solution or the test tube turned brown, and more did not observe any colour change.
- (f) While the majority of candidates were able to provide the identity of the ions correctly, many did not supply sufficient evidence for their choices. The most common error was to identify the second cation as $\text{Cr}^{3+}(\text{aq})$, and in some cases it was apparent that observations in (d) had been amended in light of their conclusion. It is important that candidates are guided by what they observe and do not try to make their observations fit the chemical they imagine they have been given.
- (g) The responses to this question varied considerably. Candidates from some Centres appeared conversant with the tests, successfully made Tollens' reagent, and were able to gain all three marks. Others lost marks by reporting the appearance of precipitates when acidified dichromate was used. The range of colours reported on warming the unknowns with the Tollens' solution were sometimes outside those expected.
- (h) The first mark was only accessible to the most able candidates as both oxidation by acidified dichromate and no reaction with Tollens' was necessary to differentiate primary and secondary alcohols from an aldehyde. More candidates gained the second mark, although still a minority. As only a ketone of the unknowns cannot be oxidised it was sufficient to report no reaction with acidified dichromate. However, if more than one unknown failed to react with the dichromate then the observation with 2,4-DNPH was needed. An incorrect response was to identify the ketone by elimination with the assumption that the four unknowns all had different functional groups. Candidates should be reminded that a greyed-out box in a table denotes no test carried out rather than a negative result of such a test. Some lost the mark by stating that **FB 9** had no reaction with Tollens'.



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Paper 9701/35

Advanced Practical Skills 31

General comments

The Examiners again 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 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 but without seating plans or candidate lists and there is insufficient data to place candidates within each Session so again candidates may be disadvantaged.

The paper generated a range of marks indicating that the more able candidates were able to answer the questions with ease whilst the weakest candidates found the paper more difficult. Every mark on the paper was awarded although several of the marks were not awarded frequently. Most candidates scored between 12 and 23 out of a possible 25 marks for **Question 1** and between 3 and 11 out of a possible 15 marks for **Question 2**.

There was little evidence of candidates failing to finish the paper in the allocated time although some weaker candidates left calculation sections blank.

Comments on specific questions

Question 1

The majority of candidates successfully performed the practical work in the question.

- (a) For the award of the first mark in this section, Examiners looked for any evidence that candidates had followed the instructions for the experiment. Temperatures of the acid were required to be recorded at 0, 1, 2 and 3 minutes, and temperatures of the cooling mixture recorded every $\frac{1}{2}$ minute between 5 and 8 minutes. Evidence for this mark was sometimes seen and credited as pencil jottings against the instructions for the experiment.

The second mark was awarded for acceptable tabulation – correct headings and correct use of units. Attention is drawn to the acceptable form of units as described in the syllabus. Some candidates were not awarded this mark as they recorded times such as 5.30 in a column headed time / minutes.

The final mark was awarded for recording all temperatures here and in the table in **(d)** to the nearest 0.5 °C and all balance readings in **(d)** to a consistent number of decimal places. A number of candidates, using a thermometer graduated at 1°C, only recorded temperatures as whole numbers. A small minority of candidates were not awarded this mark as every temperature in **(a)** was recorded to 1 decimal place – but always a zero. The Examiners consider that as out of the 12 temperatures to be recorded 7 referred to a gently cooling mixture, at least one reading should have been between graduations on the thermometer and recorded as .5 °C.

- (b)** Most candidates plotted temperature against time and correctly labelled the axes.

Most candidates selected appropriate temperature scales. The Examiners expect, as a general rule, to see points plotted over at least half of each axis.

Points were generally plotted within the ½ small square tolerance allowed by the Examiners. This was a very generous tolerance. It is to be noted however that some candidates did not take care when plotting points – those that should centre on a grid line were off that line. Some candidates, plotting a point within ½ a small square of its correct position, managed to plot the point on the “wrong side” of a grid line, i.e. in an incorrect small square. In this case the plotting mark was not awarded.

Most candidates drew appropriate straight lines and read from these lines the intercepts at t=4 minutes.

- (c)** As the expression had been given in **(i)**, all candidates were able to calculate the change in heat energy during the reaction.

Most candidates correctly calculated the moles of **FA 1** used in the experiment and the enthalpy change for 1 mole of **FA 1**. Nearly all candidates gave a correct sign and explanation of the sign.

- (d)** The two experiments in this section were generally conducted well. Balance readings were recorded with consistent precision but again some candidates failed to record all thermometer readings to the nearest 0.5 °C. The Examiners calculated $\Delta T/m$ for each experiment. Two marks were available for a comparison of the ratios obtained for each of the experiments – the candidate was assessed for consistency of working. Two marks were also available for comparing a “standard” value of 1.55 °C g⁻¹ with the closer of the two candidate values. Most candidates scored at least 2 from the four marks available.

- (e)** In **(i)** a similar calculation was performed to that in **(c)(i)**.

The moles of sodium carbonate used was generally calculated correctly in **(ii)** and the enthalpy change in **(iii)**. Again nearly all candidates gave a correct sign and explanation of the sign.

Most candidates were awarded the mark for showing working in their calculations and those who gave their answers in **(c)(iii)** and **(e)(ii)** to 2 or 3 significant figures were awarded the final mark in this section.

- (f)** Most candidates used the given expression correctly but a small number omitted the factor of ½ for the enthalpy of neutralisation of sodium carbonate or created difficulties for themselves when manipulating the signs given for the energy changes in **(c)(iii)** and **(e)(iii)**.

- (g)** Most candidates were able to calculate the difference and percentage difference to the enthalpy value obtained by an alternative method.

- (h) Most candidates were able to suggest one major source of error in the experiment and to suggest an improvement but few gave an adequate explanation as to how the suggested improvement would increase experimental accuracy. A typical answer would read:

Heat loss.
Use a lid.
Use of a lid prevents heat loss.

The Examiners wished to know that using a lid prevents heat loss by convection; using lagging prevents heat loss by conduction; using a thermometer at 0.5 °C division or better gives a smaller % error etc.

Question 2

- (a) Most candidates gave a named acid and silver nitrate as their reagents in (i). A small number of candidates incorrectly reversed the position of the reagents. Others used a named acid and lead nitrate – this was only acceptable if nitric acid was used as the named acid. Candidates should be aware that hydrochloric acid should not be used in conjunction with silver nitrate when testing for a chloride. Nitric acid is the only acid that can be used successfully with lead nitrate.

Part (ii) was one of the infrequently awarded marks. It was clear that the majority of the candidates had not read or understood the significance of the sentence about the solubility of carbonates, chlorides and nitrates. The candidates were asked to explain the order in which the reagents would be added to FA 4, FA 5 and FA 6. From the results recorded in (iii) many candidates clearly added the reagents to separate samples of FA 4, FA 5 and FA 6 without making this clear in their explanation in (ii). The Examiners were looking for an understanding that if the acid is added first it removes (as well as reveals) the carbonate before the addition of silver nitrate. If the acid was added after the silver nitrate it would dissolve the silver carbonate formed.

In (iii) some candidates recorded gas given off when the acid was added to FA 5 and FA 6 but this was not considered by the Examiners to be an observation. The evolution of gas is seen as effervescence or as bubbles in the solution or is confirmed by an appropriate chemical test on the gas. Reference to limewater was sometimes seen but the recorded observation seemed to imply that it was added to the solution. There should have been clear reference to a gas formed that turned limewater cloudy/milky etc. Where acid was added after the silver nitrate it was common to see recorded observations for the production of gas or for the solubility of the precipitate in the acid but not for both of them.

The result of imprecise observation or of adding the reagents to fresh samples was that chloride was often and incorrectly identified in all three solutions. Most candidates were able to correctly identify the two solutions containing the carbonate.

The most able candidates gained both marks in (iii) and both marks in (iv).

- (b) FA 7 was a solution containing $Al^{3+}(aq)$ ions and FA 10 a solution containing $Pb^{2+}(aq)$ ions and as such should have given a standard set of observations as listed in the Qualitative Analysis Notes. Many candidates recorded solutions when precipitates should have formed and vice versa.

FA 9 contained $Cr^{3+}(aq)$ ions and as usual with this ion observations were generally poor. Candidates should have experience of adding aqueous sodium hydroxide and aqueous ammonia to the cations listed in the Qualitative Analysis Notes. The expected observations do match the description, colour and state given in the Notes. The colour of the precipitate given with Cr^{3+} ions is distinctive as is the solubility in excess of the reagent of any precipitate formed on initial addition of the reagent.

FA 8 contained $Ni^{2+}(aq)$ ions. Candidates were not asked to identify the ions present – the Examiners were looking for careful observations. The green precipitate with aqueous sodium hydroxide, insoluble in excess of the reagent and the dark/deep blue solution with an excess of aqueous ammonia should have been observed.



In **(iii)** the reagent was to be added only to solutions that gave a white precipitate with both aqueous sodium hydroxide and aqueous ammonia – **FA 7** and **FA 10** containing $Al^{3+}(aq)$ ions and $Pb^{2+}(aq)$ ions respectively. Solutions containing chromate(VI), dichromate(VI); iodide, sulfate or chloride ions were suitable as reagents. Unfortunately a large number of candidates chose to add barium chloride but this was not a suitable reagent, as the presence of any sulfate ion would produce conflicting evidence as it did here with **FA 7**. Many candidates gave results for all the solutions with the selected reagent and so forfeited this mark.

- (c)** Most candidates were able to identify the ions present and there was usually sufficient evidence in the observations to support the conclusions. Where barium chloride was used in **(b)(iii)** the lead and aluminium ions were normally reversed in the conclusions and the deduction mark was not awarded. The mark for evidence was however awarded, if appropriate, as an error carried forward.

In giving evidence to support the identity of the cations many candidates copied their evidence from the Qualitative Analysis Notes – even where this contradicted the recorded observations. This was often the case with the evidence for the chromium(III) ion

The Examiners would encourage candidates to describe their observations in similar terms to those used in the Qualitative Analysis Notes.

CHEMISTRY

<p>Paper 9701/41 A2 Structured Questions 4</p>
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General Comments

This paper provided candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of Chemistry. Candidates who were well-prepared for the examination were able to tackle all of the questions. There was no evidence that candidates had insufficient time to complete the paper.

Comments on Individual Questions

Question 1

- (a) Candidates' observations were generally poor, with incorrect flame colours or descriptions of gases. The equations were mostly correct, although a worrying number seemed unable to balance equations.
- (b)(i) Most candidates were able to balance this equation.
- (ii) The answers here were variable, many scored full marks but others did not seem to understand what was required.
- (iii) A few candidates scored full marks here, but many did not show all four phosphorus atoms in P_4 as trivalent, and did not indicate a clear structure for the polymeric nature of red phosphorus.

Question 2

- (a) This part was generally answered well, although a few candidates described physical rather than chemical properties and could not be credited.
- (b) In comparison to (a) this was not well-answered. Many candidates did not recognise the precipitate as $Ni(OH)_2$, and few gave balanced equations.
- (c) This part showed a clear distinction between candidates familiar with chemical calculations and those less so, with some attempting the calculation without determining the M_r value of Ni-DMG.

Question 3

- (a) This part was generally well-answered.
- (b)(i) Although this was often well-understood, the use of E^\ominus data both here and in (a) was not common.
- (ii) Lots of candidates failed to score here because they made no comparison with $PbCl_4$.
- (c)(i) This scored well, with lots of candidates gaining full marks, although some showed 6 electrons in the outer shell of carbon.
- (ii) Most candidates were able to write a balanced equation.

Question 4

- (a) Most candidates correctly stated 'hydrogen bonding', but fewer were able to draw acceptable diagrams, and a significant number showed H-bonds to water.
- (b) Many candidates were aware that propylamine was the more basic, but only a small proportion were able to explain why, and a large number failed to include the lone pair on nitrogen in their answers.
- (c) Although a good number of candidates wrote acceptable equations, a worrying number failed to give an equation that showed they understood Brønsted-Lowry acids and bases.
- (d)(i) A significant number of candidates did not recognise what the intermediate was.
- (ii) There are still a significant number of candidates who think that HCN is the reagent here.
- (e) This was generally well-answered although some candidates confused the structures of the two compounds and muddled the tests.

Question 5

Overall this was the lowest scoring question on the paper. Candidates showed the usual confusion in using E^\ominus data which resulted in a number of lost marks. Candidates also lacked a detailed knowledge of how to use concentration data in cells (learning outcome 6(i)).

- (a)(i) A number of candidates used the data for acid solution, or chose one electrode in acid and one in alkaline solution and hence calculated the wrong E_{cell} .
- (ii) This was very poorly done with most equations left unbalanced with surplus OH^- ions or H_2O molecules on one or other side of the equation.
- (iii) Very few completely correct answers were seen as many candidates did not apply the logic required.
- (iv) This depended on (iii) and was also badly done. It was expected that candidates would deduce the change in electrode potential of each electrode in (iii) and then use this to work out that the E_{cell} was the difference between them.
- (v) There were some good answers here in terms of increased rate or better conductivity, but there were a lot of guesses too.
- (b)(i) The most common error was to use E^\ominus for Pb^{4+} rather than for PbO_2 .
- (ii) There were a pleasing number of correct equations here.
- (iii) By contrast, equations here were often poor with hydrogen gas being produced.
- (iv) A large number of candidates appeared to guess here with extremely few correct explanations.

Question 6

- (a)(i) A pleasing number of candidates managed to identify a suitable reagent.
- (ii) Unfortunately not all of those who could give the reagent were able to write a balanced equation for the reaction.

- (b)(i) There were a large number of poor drawings of structures here. Candidates must show the correct atoms bonded in the right sequence or risk penalty. A significant number lost a mark here for showing either oxygen or nitrogen bonded to the ring rather than carbon.
- (ii) Most candidates scored at least one of the marks here.
- (iii) A significant number of candidates gave an electrophilic substitution here rather than the correct nucleophilic substitution.
- (c)(i) The identification of **C** and **D** was generally poor, with candidates ignoring the statement in the stem that both were acyl chlorides.
- (ii) This was much more successfully answered, with most candidates knowing that this was hydrogen bonding.
- (iii) Very poorly answered with some candidates apparently confusing which way the pH scale runs.
- (iv) Generally well answered.

Question 7

This question proved very testing and discriminated well between good and very good candidates. A concern was that a significant number of candidates were not comfortable using skeletal formulae despite their prominence in the syllabus for a number of years now.

Question 8

- (a) This part was well-answered with a significant number of candidates scoring good marks. The most common error (other than spelling) was to confuse the deoxyribose and phosphate.
- (b) This was well-answered.
- (c) Again candidates clearly knew the differences between DNA and RNA.
- (d) This part was less-well answered with a number of candidates apparently relying on their knowledge from biology and not focusing on the chemical principles.

Question 9

- (a) This was very poorly answered with few candidates scoring both of the marks. Few could adequately explain two spin-states for a proton and a large number omitted to mention any external magnetic field.
- (b) This was again poorly answered, with a significant number of candidates reading 'relative areas' to mean 'relative positions'. Even so, when they used the Data Booklet they gave values for absorptions that were not present in the spectrum shown.
- (c)(i) Answers here were very disappointing with many candidates unable to draw correct structures for the named compounds. In some cases they even failed to draw compounds that were isomers of one another.
- (ii) For reasons that are unclear, a number of candidates seemed to think that peaks **A** and **B** came from different compounds and did not refer back to the spectrum they had been given.
- (iii) This was more successfully answered.
- (d)(i) Candidates were generally not clear in what information they thought that X-ray crystallography could provide and some merely repeated what was stated in the question.
- (ii) Although most candidates knew that this was hydrogen, there was a range of incorrect answers that suggested this may not have been taught to all candidates.



Question 10

- (a) It was expected from the stem of this question that candidates would think about acid hydrolysis and hence give ester or amide (or possibly nitrile) as the answer. A significant number incorrectly gave alcohol or amine as answers.
- (b) This was very poorly answered with candidates often ignoring the instruction to circle bonds and circling individual atoms instead. Those who followed the instructions sometimes circled C=O or –OH bonds incorrectly.
- (c)(i) This was generally well-answered with candidates correctly identifying hydrophilic and hydrophobic environments within the liposome.
- (ii) Once again there were some good answers here, but some of those who scored the mark in the earlier part were unclear about the reason why position **A** was unsatisfactory.
- (d)(i) Despite the limited choices available, a significant number of candidates failed to score this easy mark.
- (ii) Candidates did not seem to take into account the likely relative sizes of a PEG molecule compared with a liposome, in particular the volume of the latter and the two different environments present.
- (e) Answers here were generally sensible and, in the main, were based on scientific logic.



CHEMISTRY

Paper 9701/42
A2 Structured Questions 4

General comments

Examiners found the usual range of standard in candidates. Good Centres seem to be getting better, but some of the less good Centres had many candidates that struggled with the harder questions. There was very little evidence of candidates running out of time, and for the most part candidates wrote clearly and legibly.

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

Comments on specific questions

Section A

Question 1

- (a) Since the question did not specify the type of formula that was required, either molecular, structural, displayed or skeletal formulae were acceptable. Many candidates incorrectly gave the sodium alkoxide + HCl as the products. Either Cl^- or NaCl was accepted for the inorganic product.
- (b)(i) Many candidates scored this mark. The most common error was to miss out the last four words of the standard definition “the exponent/power to which a reactant’s concentration is raised *in the rate equation*”.
- (ii) While most candidates scored a mark for the correct orders (first order in each reagent), many did not explain their reasoning well enough for the second mark. Comments such as “rate doubles as $[\text{RC}]$ doubles, therefore first order” were not accepted, since the data do not include any lines where the $[\text{RC}]$ has doubled.
- (iii) This was marked consequentially on the candidate’s conclusions in (ii). Some gained no mark due to the omission of the rate constant, k , in their equation.
- (iv) This part was done very poorly indeed by the vast majority of candidates. Despite it being clearly on the syllabus, the details of this mechanism were not clearly expressed. Very few candidates did as they were asked in the question: rarely did Examiners see the δ^+ and δ^- indicated on the C-Cl bond, and even more rarely was there to be seen a lone pair of electrons in the OH^- ion. The curly arrows tended to start and finish in thin air, or definitely at the wrong place – many were shown finishing at the Cl end of the C-Cl bond. The mechanism was marked consequentially on the rate equation the candidates gave in (iii). Thus if the rate was said to be second order, the $\text{S}_{\text{N}}2$ mechanism was expected. A number of candidates did not interpret the skeletal formula of phenacyl chloride correctly, and drew a mechanism using benzoyl chloride.
- (c)(i) This part was also poorly answered. The preferred reagent was $\text{AgNO}_3(\text{aq})$, which would give a white ppt. of AgCl at a faster rate with ethanoyl chloride than with phenacyl chloride. An acceptable alternative was to use a *named* indicator (e.g. methyl orange – but NOT phenolphthalein, which would not change colour from neutral to acidic solution), and describe the colour change that would be seen (orange to red). Steamy fumes would only be observed if a *small amount* of water was used.

- (ii) Few candidates gave a clear explanation here: the presence of *two* electronegative atoms would cause the carbon atom to have a **greater $\delta+$ charge** in ethanoyl chloride than in phenacyl chloride. Although the alternative (and perhaps the more correct) explanation in terms of the acyl chloride reacting via an addition-elimination mechanism would have been credited, this is beyond the syllabus, so was not expected. It was seen on a few scripts, however. Many candidates incorrectly wrote about delocalisation (of charge) over the benzene ring in phenacyl chloride making it more stable.

Question 2

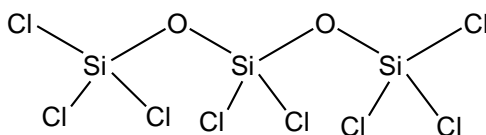
- (a) This was well answered, with most candidates scoring full marks.
- (b)(i) This was also fairly well answered, but some candidates forgot to multiply the enthalpy change of hydration of $\text{OH}^-(\text{g})$ by 2, thus getting values of +553 and +503 kJ mol^{-1} for $\text{Mg}(\text{OH})_2$ and $\text{Sr}(\text{OH})_2$ respectively. The usual problems with mixing up signs also occurred.
- (ii) This part, and (iii), were marked consequentially on the candidate's answers in (i). Most candidates correctly related the relative solubilities to ΔH values, but few stated the essential assumption that needed to be made. A mark was awarded for mentioning that the temperature would need to be the same in each case. Allowance was also made if the candidates pointed out, as an alternative, that the entropy of solution needs to be assumed to be the same in each case.
- (iii) This was also fairly well answered, although a significant number of candidates argued that $\text{Sr}(\text{OH})_2$ would be more soluble in hot water for kinetic reasons, forgetting that *solubility* is an equilibrium process.
- (c)(i) This was well answered by the majority of candidates. Errors included omitting one or both of the ionic charges; including a "2" before the OH^- term; and not squaring the $[\text{OH}^-]$. The units were marked consequentially on the K_{sp} expression given.
- (ii) Several candidates were confused about where to multiply or divide by 2 in this calculation. Rather than taking this to be, initially, a simple acid-base titration calculation, with the HCl and OH^- reacting in a 1:1 ratio, they chose to calculate first the $[\text{Ca}(\text{OH})_2(\text{aq})]$, and then work back to find $[\text{OH}^-(\text{aq})]$ and $[\text{Ca}^{2+}(\text{aq})]$, with the inevitable slips appearing.
- (iii) This was very well answered. Most candidates recognised the common ion effect at work, and explained this well.

Question 3

- (a) The mark scheme allowed two alternative approaches – either to explain how the four Si-F dipole cancel each other in SiF_4 , due to their tetrahedral arrangement, or to point out that SF_4 contains one lone pair, which inevitably would cause an asymmetric distribution of charge. Correct answers were seen from most candidates, with slightly more opting for the lone pair approach.
- (b) Despite the good reasoning shown in (a), quite a number of candidates did not apply it to (b). Only PCl_3 has a lone pair, the other molecules having a symmetrical distribution of bonds and hence charge.
- (c)(i) Many candidates knew the "Si has d orbitals" justification, but only a minority applied it intelligently. Carbon - and boron, as it happens - both have 3d orbitals, of course, but they are too high in energy to be used in bonding. Current theory suggests that the 3d orbitals in silicon are also too high in energy! However, since this is such a common reason given for the reactivity of SiCl_4 , it would have been accepted by Examiners. But a large number of candidates did not consider clearly enough the Periodic Table position of boron, and suggested that it too could utilise its 3d orbitals. Being in Period 2, there is no way that boron could do this, since the 3d orbital is far too high in energy. Instead, though, it can use its spare, unoccupied, 2p orbital.
- (ii) Many candidates knew the reaction between SiCl_4 and water, but fewer could write an equation for the reaction between BCl_3 and water. Either H_3BO_3 or B_2O_3 were accepted as products.

(d)(i) (ii) In general, both these parts were poorly answered. This was, perhaps, a novel way in which to assess syllabus learning outcome 1(c), but many gave up before they had written much working down on paper. Taking just the highest peak in the mass spectrum, at mass number 396, and knowing that this has the formula $\text{Si}_x\text{Cl}_y\text{O}_z$, there are only three possibilities: $\text{Si}_3\text{Cl}_8\text{O}_2$, $\text{Si}_4\text{Cl}_4\text{O}_9$ or $\text{Si}_8\text{Cl}_4\text{O}_2$. The easiest way to distinguish between these three (and, indeed, the easiest way to have generated the molecular formula in the first place), would be to look at the other peaks in the mass spectrum. Mass number 133 corresponds to SiCl_3 (the only one that most candidates identified in part (ii)); 149 is 16 a.m.u. higher, so is likely to be SiCl_3O ; 247 is 98 a.m.u. higher still, which corresponds to an additional SiCl_2 . Lastly, 263 represents an additional 16 a.m.u. (= one oxygen atom), so can be identified with $\text{Si}_2\text{Cl}_5\text{O}_2$. This is 133 a.m.u. less than the molecular ion, and thus represents the loss of SiCl_3 . Thus the three structures required in the table are SiCl_3 , $\text{SiCl}_3\text{-O-SiCl}_2$ and $\text{SiCl}_3\text{-O-SiCl}_2\text{-O}$.

(iii) The structure expected was



However, any structure showing the right valencies and with the correct M_r was accepted.

Question 4

- (a)** Most candidates scored well here, although some thought the ions still contained $4s^2$ electrons, and others forgot to include the $3s^23p^6$ electrons.
- (b)(i)** This part was poorly answered. It was clear that many candidates were not thinking their way through a real-life laboratory situation – perhaps they had never seen it themselves. Thus they described the colour change that the Fe^{2+} would undergo and, *separately*, the colour change the KMnO_4 would undergo, without appreciating that once the one had been added to the other, only a single solution results. Thus descriptions such as “the FeSO_4 would change from green to brown, whereas the KMnO_4 would change from purple to colourless” did not impress Examiners. The sequence of colours observed would be as follows: pale green \rightarrow colourless (or pale yellow) \rightarrow pink \rightarrow purple.
- (ii)** Candidates were better at writing the equation. Some, however, chose to oxidise Fe to Fe^{2+} , rather than Fe^{2+} to Fe^{3+} .
- (c)** Candidates showed the usual difficulty in using E^\ominus values to predict reactions. Often, they only quoted the E^\ominus values for $\text{Fe}^{3+}/\text{Fe}^{2+}$ and $\text{Fe}(\text{OH})_3/\text{Fe}(\text{OH})_2$, and attempted to predict reactivity based on these electrode voltages, rather than the voltages of complete cells. Two other E^\ominus values were needed: those for $\text{O}_2/\text{H}_2\text{O}$ in acidic and alkaline solution. Coupling the correct E^\ominus values with each other produces voltages of +0.46V in acidic solution, and +0.96V in alkaline solution. Hence it can be seen that the E^\ominus_{cell} is more positive in alkaline solution.
- (d)** Candidates made a fair attempt at this part, but there were many confused answers. The first compound would be oxidised at the double bond to cyclohexanone and ethanoic acid (quite a few thought that cyclohexanone contained a benzene ring!); the second to benzene 1,4-dicarboxylic acid. The secondary alcohol group in the third compound would be oxidised to a ketone, whereas the primary group could be oxidised to either an aldehyde or a carboxylic acid, depending on the conditions – reflux or distil (which were not stated).
- (e)** Most candidates thought that **E** was $(\text{CH}_3)_2\text{C}(\text{OH})_2$ rather than $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{OH}$. Cold KMnO_4 would produce the diol from the alkene in reaction I, and acidified $\text{K}_2\text{Cr}_2\text{O}_7$ *with distillation* would produce the aldehyde in reaction II.

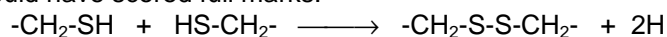


Question 5

- (a) This part targeted learning outcomes 3(e) and 10.1(d). This topic has not been set before, and it was clear that candidates did not have a clear idea of these explanations.
- (i) There are many ways of briefly explaining (in only three lines) why benzene is planar, and any of the following alternatives was accepted:
- either* because the carbons are sp^2 /trigonal planar/bonded at 120°
or are joined by π bonds or π orbitals.
- (ii) Likewise, alternatives were accepted here:
either because the π electrons/double bonds are delocalised
or electrons are evenly distributed/spread out.
- (b)(i) The *initial* role is that of an acid, protonating nitric acid: $H_2SO_4 + HNO_3 \longrightarrow HSO_4^- + H_2NO_3^+$.
However, the “usual” equation producing the nitronium ion was also accepted here.
- (ii) Surprisingly, several candidates wrote incorrect reaction types: *nucleophilic substitution* and *electrophilic addition* were the two most common incorrect answers. The mechanism was fairly well drawn out, although once again the positions of curly arrows were too vague in several cases (see also comments on **Question 1** above). Two curly arrows were required: one from the ring of electrons within the hexagon to the NO_2^+ ion, and the other from the H-C bond back into the ring, showing the loss of the proton.
- (c) Chlorine and a Freidel-Crafts catalyst such as aluminium chloride were required here. Some candidates forfeited the mark by mentioning light or water (aq) as conditions. Others forgot to include the reagent.
- (d)(i) Despite the preamble to this part of the question, several candidates inserted the nitro group first. Still others then went on to reduce this to an $-NH_2$ group, and insert a single chlorine with $Cl_2(aq)$ (or worse; $Cl_2 + AlCl_3$) in the third step. Phenylamine is so reactive that even $Cl_2(aq)$ would produce tri-substitution.
- (ii) Most candidates correctly quoted Sn + hydrochloric acid as the reagents, although some considered that tin was a catalyst, rather than a reagent. The acid needs to be HCl , and it needs to be concentrated. The second step – making the solution alkaline with NaOH, so as to liberate the free base – was often omitted.
- (iii) This part was, in general, well answered. The production of **A** involves the insertion of two Br atoms into the ring; **B** is the ethanamide $Ar-NHCOCH_3$. The chloro-amine would not react with NaOH, due to the chlorine being directly attached to the aryl ring. Thus **E** is “no reaction”. Because no temperature was specified, compound **D** could either be the diazonium cation (charge required) or the chlorophenol – formed from the diazonium ion and water. Some candidates lost marks in this part through carelessness: they did not show the correct atoms joined to the ring. Thus for **B**, structures showing the CO or the CH_3 next to the ring were not credited. Also, candidates should be aware that the correct convention to use when writing out structural formula is the one that places hydrogen atoms to the right of chain atoms. Thus $-NHCOCH_3$ is correct; $-NHOCH_3C$ is not.

Question 6

- (a) This was well-known bookwork, and was answered well by most candidates.
- (b)(i) Less well-known was the make-up of the disulfide bond. The following equation represents the process, and would have scored full marks.



Quite a number of candidates did not appreciate that a covalent bond was being formed, and drew structures with dotted lines between S atoms.

- (ii) Most candidates incorrectly suggested this was a condensation reaction. Had they written the above equation in (i), it would have been clear to them that this is a dehydrogenation, or oxidation, reaction.
- (iii) Most scored well here. The term “hydrophobic interaction” was ignored by Examiners. This is a non-specific term borrowed from biologists. Van der Waals attractions, hydrogen bonding, and ionic attractions (or salt bridges) were required for full marks. “Electrostatic attractions” was also ignored: all chemical attractions are electrostatic in nature.
- (c) (i) The vast majority of candidates gained this mark.
- (ii) Many scored full marks here also, but some did not show both of the ways in which H-bonds could form: from the N-H groups on the original, and on the new chain.
- (d) Very few scored marks here. There was a common misconception that there were more hydrogen bonds in the β -sheet of β -keratin than there were in silk. Candidates should be aware that all β -sheets contain (roughly) the same density of hydrogen bonds – between the C=O and N-H groups in the peptide bonds of adjacent chains. The side chains poke up and down from the plane of the sheet. It is the interactions of these side chains *between the sheets* that is important for flexibility: if these interactions are weak van der Waals (as in silk, with glycine and alanine residues), then the sheets are flexible, if, however, the interactions are covalent S-S bridges, then the sheets cannot slide over each other so easily, and so are more rigid.

Question 7

- (a) Quite a number of candidates thought that the reason lay in the large size of the amino acid, rather than its charge being zero (i.e. it is at its isoelectric point, existing as a zwitterion). With no charge, it would not be attracted to either electrode, and so would remain stationary.
- (b) Most candidates correctly deduced that the ion $\text{NH}_2\text{CH}_2\text{CO}_2^-$ would form. Some got the wrong end of the stick, and wrote $\text{NH}_3^+\text{CH}_2\text{CO}_2\text{H}$.
- (c) This was well answered by the majority of candidates.
- (d) (i) This was answered in a much better manner than the last time a question of this sort was set, and Examiners were pleased with what they saw. Apart from the correct octa-peptide, common wrong answers were a hexa-peptide (omitting an ala-gly in the middle) and a deca-peptide (including an *extra* ala-gly in the middle!).
- (ii) Most candidates scored a mark here. Some, however, confused “tripeptide” with “amino acid”, and wrote “glycine”.
- (iii) Either lysine or aspartic acid was accepted.

Question 8

- (a) The question carefully avoided the use of the terms “anode” and “cathode”, since these mean different things when applied to either electrochemical cells or electrolysis cells. Only a small number of candidates explained that since reaction II is using up electrons (presumably from the external circuit) then this must be the one occurring at the positive electrode.
- (b) Many scored a mark here. The most common incorrect values were 1.34 V (adding the two E^\ominus values rather than subtracting one from the other), and 1.82 V (using the E^\ominus for $\text{Pb}^{4+}/\text{Pb}^{2+}$ rather than that for $\text{PbO}_2/\text{Pb}^{2+}$).
- (c) (i) Many calculated the correct value of +3.
- (ii) The most common correct answer was that the nickel batteries would be less heavy. Other possibilities included that they would be less toxic or polluting.

- (d)(i)** Many correctly suggested platinum or graphite, but some forfeited the mark by suggesting it was then coated in nickel.
- (ii)** Despite the stem of this part of the question, many candidates homed in on the expense of platinum, rather than a property of hydrogen. Its combustibility was correctly pointed out by some. Others scored a mark for pointing out that it would need to be kept under pressure, or liquefied, which would be difficult since it has a very low boiling point.
- (e)** Perhaps it was because this was the last question on the paper, but several candidates did not read its preamble carefully enough. Most said that plastics needed recycling because of the pollution caused by their non-bio-degradability.

The question confined itself to saving energy or resources (or both). Several candidates also reckoned that the raw material for making glass ("silicon") was scarce! However, many did state that it was more energy-consuming to make glass from scratch than to re-melt used glass; that recycling steel was important because iron ores were becoming scarce, and it took a lot of energy to reduce the ore to the metal (iron); and finally that plastics are made from oil – a diminishing resource.

CHEMISTRY

Paper 9701/43
A2 Structured Questions 4

General comments

Examiners found the usual range of standard in candidates. Good Centres seem to be getting better, but some of the less good Centres had many candidates that struggled with the harder questions. There was very little evidence of candidates running out of time, and for the most part candidates wrote clearly and legibly.

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

Comments on specific questions

Section A

Question 1

- (a) Since the question did not specify the type of formula that was required, either molecular, structural, displayed or skeletal formulae were acceptable. Many candidates incorrectly gave the sodium alkoxide + HCl as the products. Either Cl^- or NaCl was accepted for the inorganic product.
- (b) (i) Many candidates scored this mark. The most common error was to miss out the last four words of the standard definition “the exponent/power to which a reactant’s concentration is raised *in the rate equation*”.
- (ii) While most candidates scored a mark for the correct orders (first order in each reagent), many did not explain their reasoning well enough for the second mark. Comments such as “rate doubles as $[\text{RC}]$ doubles, therefore first order” were not accepted, since the data do not include any lines where the $[\text{RC}]$ has doubled.
- (iii) This was marked consequentially on the candidate’s conclusions in (ii). Some gained no mark due to the omission of the rate constant, k , in their equation.
- (iv) This part was done very poorly indeed by the vast majority of candidates. Despite it being clearly on the syllabus, the details of this mechanism were not clearly expressed. Very few candidates did as they were asked in the question: rarely did Examiners see the δ^+ and δ^- indicated on the C-Cl bond, and even more rarely was there to be seen a lone pair of electrons in the OH^- ion. The curly arrows tended to start and finish in thin air, or definitely at the wrong place – many were shown finishing at the Cl end of the C-Cl bond. The mechanism was marked consequentially on the rate equation the candidates gave in (iii). Thus if the rate was said to be second order, the $\text{S}_{\text{N}}2$ mechanism was expected. A number of candidates did not interpret the skeletal formula of phenacyl chloride correctly, and drew a mechanism using benzoyl chloride.
- (c) (i) This part was also poorly answered. The preferred reagent was $\text{AgNO}_3(\text{aq})$, which would give a white ppt. of AgCl at a faster rate with ethanoyl chloride than with phenacyl chloride. An acceptable alternative was to use a *named* indicator (e.g. methyl orange – but NOT phenolphthalein, which would not change colour from neutral to acidic solution), and describe the colour change that would be seen (orange to red). Steamy fumes would only be observed if a *small amount* of water was used.
- (ii) Few candidates gave a clear explanation here: the presence of *two* electronegative atoms would cause the carbon atom to have a **greater δ^+ charge** in ethanoyl chloride than in phenacyl chloride. Although the alternative (and perhaps the more correct) explanation in terms of the acyl chloride reacting via an addition-elimination mechanism would have been credited, this is beyond the

syllabus, so was not expected. It was seen on a few scripts, however. Many candidates incorrectly wrote about delocalisation (of charge) over the benzene ring in phenacyl chloride making it more stable.

Question 2

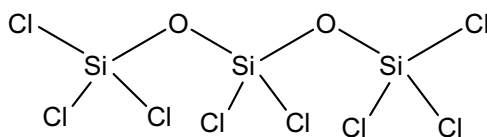
- (a) This was well answered, with most candidates scoring full marks.
- (b) (i) This was also fairly well answered, but some candidates forgot to multiply the enthalpy change of hydration of $\text{OH}^-(\text{g})$ by 2, thus getting values of +553 and +503 kJ mol^{-1} for $\text{Mg}(\text{OH})_2$ and $\text{Sr}(\text{OH})_2$ respectively. The usual problems with mixing up signs also occurred.
- (ii) This part, and (iii), were marked consequentially on the candidate's answers in (i). Most candidates correctly related the relative solubilities to ΔH values, but few stated the essential assumption that needed to be made. A mark was awarded for mentioning that the temperature would need to be the same in each case. Allowance was also made if the candidates pointed out, as an alternative, that the entropy of solution needs to be assumed to be the same in each case.
- (iii) This was also fairly well answered, although a significant number of candidates argued that $\text{Sr}(\text{OH})_2$ would be more soluble in hot water for kinetic reasons, forgetting that *solubility* is an equilibrium process.
- (c) (i) This was well answered by the majority of candidates. Errors included omitting one or both of the ionic charges; including a "2" before the OH^- term; and not squaring the $[\text{OH}^-]$. The units were marked consequentially on the K_{sp} expression given.
- (ii) Several candidates were confused about where to multiply or divide by 2 in this calculation. Rather than taking this to be, initially, a simple acid-base titration calculation, with the HCl and OH^- reacting in a 1:1 ratio, they chose to calculate first the $[\text{Ca}(\text{OH})_2(\text{aq})]$, and then work back to find $[\text{OH}^-(\text{aq})]$ and $[\text{Ca}^{2+}(\text{aq})]$, with the inevitable slips appearing.
- (iii) This was very well answered. Most candidates recognised the common ion effect at work, and explained this well.

Question 3

- (a) The mark scheme allowed two alternative approaches – either to explain how the four Si-F dipole cancel each other in SiF_4 , due to their tetrahedral arrangement, or to point out that SF_4 contains one lone pair, which inevitably would cause an asymmetric distribution of charge. Correct answers were seen from most candidates, with slightly more opting for the lone pair approach.
- (b) Despite the good reasoning shown in (a), quite a number of candidates did not apply it to (b). Only PCl_3 has a lone pair, the other molecules having a symmetrical distribution of bonds and hence charge.
- (c) (i) Many candidates knew the "Si has d orbitals" justification, but only a minority applied it intelligently. Carbon - and boron, as it happens - both have 3d orbitals, of course, but they are too high in energy to be used in bonding. Current theory suggests that the 3d orbitals in silicon are also too high in energy! However, since this is such a common reason given for the reactivity of SiCl_4 , it would have been accepted by Examiners. But a large number of candidates did not consider clearly enough the Periodic Table position of boron, and suggested that it too could utilise its 3d orbitals. Being in Period 2, there is no way that boron could do this, since the 3d orbital is far too high in energy. Instead, though, it can use its spare, unoccupied, 2p orbital.
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(d)(i)(ii) In general, both these parts were poorly answered. This was, perhaps, a novel way in which to assess syllabus learning outcome 1(c), but many gave up before they had written much working down on paper. Taking just the highest peak in the mass spectrum, at mass number 396, and knowing that this has the formula $\text{Si}_x\text{Cl}_y\text{O}_z$, there are only three possibilities: $\text{Si}_3\text{Cl}_8\text{O}_2$, $\text{Si}_4\text{Cl}_4\text{O}_9$ or $\text{Si}_6\text{Cl}_4\text{O}_2$. The easiest way to distinguish between these three (and, indeed, the easiest way to have generated the molecular formula in the first place), would be to look at the other peaks in the mass spectrum. Mass number 133 corresponds to SiCl_3 (the only one that most candidates identified in part (ii)); 149 is 16 a.m.u. higher, so is likely to be SiCl_3O ; 247 is 98 a.m.u. higher still, which corresponds to an additional SiCl_2 . Lastly, 263 represents an additional 16 a.m.u. (= one oxygen atom), so can be identified with $\text{Si}_2\text{Cl}_5\text{O}_2$. This is 133 a.m.u. less than the molecular ion, and thus represents the loss of SiCl_3 . Thus the three structures required in the table are SiCl_3 , $\text{SiCl}_3\text{-O-SiCl}_2$ and $\text{SiCl}_3\text{-O-SiCl}_2\text{-O}$.

(iii) The structure expected was



However, any structure showing the right valencies and with the correct M_r was accepted.

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- (b)(i) This part was poorly answered. It was clear that many candidates were not thinking their way through a real-life laboratory situation – perhaps they had never seen it themselves. Thus they described the colour change that the Fe^{2+} would undergo and, *separately*, the colour change the KMnO_4 would undergo, without appreciating that once the one had been added to the other, only a single solution results. Thus descriptions such as “the FeSO_4 would change from green to brown, whereas the KMnO_4 would change from purple to colourless” did not impress Examiners. The sequence of colours observed would be as follows: pale green → colourless (or pale yellow) → pink → purple.
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- (e) Most candidates thought that **E** was $(\text{CH}_3)_2\text{C}(\text{OH})_2$ rather than $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{OH}$. Cold KMnO_4 would produce the diol from the alkene in reaction I, and acidified $\text{K}_2\text{Cr}_2\text{O}_7$ with distillation would produce the aldehyde in reaction II.

Question 5

(a) This part targeted learning outcomes 3(e) and 10.1(d). This topic has not been set before, and it was clear that candidates did not have a clear idea of these explanations.

(i) There are many ways of briefly explaining (in only three lines) why benzene is planar, and any of the following alternatives was accepted:

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However, the “usual” equation producing the nitronium ion was also accepted here.

(ii) Surprisingly, several candidates wrote incorrect reaction types: *nucleophilic substitution* and *electrophilic addition* were the two most common incorrect answers. The mechanism was fairly well drawn out, although once again the positions of curly arrows were too vague in several cases (see also comments on **Question 1** above). Two curly arrows were required: one from the ring of electrons within the hexagon to the NO_2^+ ion, and the other from the H-C bond back into the ring, showing the loss of the proton.

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Question 6

- (a) This was well-known bookwork, and was answered well by most candidates.
- (b)(i) Less well-known was the make-up of the disulfide bond. The following equation represents the process, and would have scored full marks.
- $$-\text{CH}_2\text{-SH} + \text{HS-CH}_2\text{-} \longrightarrow -\text{CH}_2\text{-S-S-CH}_2\text{-} + 2\text{H}$$
- Quite a number of candidates did not appreciate that a covalent bond was being formed, and drew structures with dotted lines between S atoms.
- (ii) Most candidates incorrectly suggested this was a condensation reaction. Had they written the above equation in (i), it would have been clear to them that this is a dehydrogenation, or oxidation, reaction.
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- (d) (i) Many correctly suggested platinum or graphite, but some forfeited the mark by suggesting it was then coated in nickel.
- (ii) Despite the stem of this part of the question, many candidates homed in on the expense of platinum, rather than a property of hydrogen. Its combustibility was correctly pointed out by some. Others scored a mark for pointing out that it would need to be kept under pressure, or liquefied, which would be difficult since it has a very low boiling point.
- (e) Perhaps it was because this was the last question on the paper, but several candidates did not read its preamble carefully enough. Most said that plastics needed recycling because of the pollution caused by their non-bio-degradability.

The question confined itself to saving energy or resources (or both). Several candidates also reckoned that the raw material for making glass ("silicon") was scarce! However, many did state that it was more energy-consuming to make glass from scratch than to re-melt used glass; that recycling steel was important because iron ores were becoming scarce, and it took a lot of energy to reduce the ore to the metal (iron); and finally that plastics are made from oil – a diminishing resource.



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Planning, Analysis and Evaluation 5

General comments

The paper provided some questions which were accessible to all the candidates and others that required more substantial consideration. Some part questions proved to be difficult to answer but correct responses to all the questions were seen and each candidate had a similar attainment on each question. The marks awarded to the whole entry ranged from the high 20's to low single figures and therefore covered virtually the entire mark range with a good distribution. There was no evidence that the paper was too long or too short nor any real difficulties in coping with the subject matter of the questions.

Question 1 and to a greater extent **Questions 2** and **3** provided a great deal of information about the experiments and associated data which is crucial to the production of a satisfactory answer. It may be that, in general, candidates do not assign enough time to considering this information.

An enhanced familiarity with experimental techniques would, it is felt, be of benefit to all candidates.

Comments on specific questions

Question 1

- (a) Most candidates provided a suitable volume given that some sulfuric acid needed to be added and that there was an upper volume limit of 150 cm^3 . It was disappointing to see some giving over 150 cm^3 . The second part of the question required a "double" calculation of stoichiometric ratio and the two different concentrations. Whilst many achieved this, most of the rest calculated with only the concentration ratio. A few gave an answer in moles (the stem required a volume).

Graphs were usually correctly sketched with an increase followed by a decrease in a straight or curved line. A few gave a single decrease which conflicted with the advice in the question. Most who failed to score did not label the neutralisation point as required in the stem.

- (b) Most correctly identified the volume of acid as the independent variable. Candidates should be advised to avoid the ambiguity in the use of "amount" in questions such as this.

Even though the question specified a fixed volume of sodium hydroxide most incorrect answers gave this volume as the dependent variable.

Very few suggested any other reasonable variables to be controlled, mostly suggesting a variety of environmental factors.

- (c) The majority correctly gave "burette", but there were a significant minority with "measuring cylinder".
- (d) This question was generally not understood. The emphasis was on control, for example, in adding the reagent in successive portions.
- (e) The two risks were generally not well done. Heat was often given – but only high heat would be acceptable as the reaction was given as exothermic. Melting cups were common (perhaps caused by the concentrated sodium hydroxide) as was heat lost to the surroundings. Few referred to the instability of the plastic cup. Few referred to the corrosive nature of the sodium hydroxide, usually giving it as irritant.

- (f) Minimising the risks was also not well done. The minimisation needed to be related to the risk not just a general precaution to take. Many stated placing in a beaker but had not related it to the cup tipping over. The corrosive nature of the sodium hydroxide required more than one precaution.
- (g) Many gained both marks here, fulfilling the requirement for four columns of data, one of acid volume and three of temperature. The usual error was the lack of units or the failure to use a correct unit or the lack of a forward slash or brackets with the unit.
- (h) Most candidates knew the required relationship but did not correctly apply it. Most used only one volume, whereas it was necessary to have the numerical data for both the acid and alkali added together. Some used sample temperature data instead of ΔT which was a good alternative approach.
- (i) Very few scored well on this question. The layout of the question prompted a response for a sign and most correctly responded. Few converted the answer to (h) into kJ. Only the more aware candidates used the moles of alkali (equal to the moles of water) to produce an answer in kJmol^{-1} . Often quoted was a non defined “moles” or moles of acid. Either a numerical or algebraic statement of moles was acceptable.

Question 2

- (a) The two anomalies proved to be difficult to get. Most gave the most obvious (97.8, 6th row 4th column) and gave just this single answer. The second (90.6) was more difficult to find. Some candidates gave a large number of anomalies (an unlikely situation) and were distracted by, for example, four items of data that were in two groups.
- (b) Most candidates gained both these marks for the mixture composition and the average boiling temperature.
- (c) Of the three marks available here most candidates scored two. A common fault was the failure to label all the four axes. Mis-plotting was seen, usually as a consequence of unusual scales. Of the two lines, the first (a straight line) was usually well done. The second line was more challenging requiring a sensible smooth curve through the points. Many candidates had some sections of straight lines in the place of curves, even sometimes connecting all the points with a series of straight lines.

As a general rule, more care and thought needs to be devoted to scaling the axes. A few candidates did not start the x axis at 0% probably misunderstanding the guidance about the temperature scale, so could not plot the first points. Many chose unsuitable scales for the temperature (y axis). A few had compacted scales that did not use at least half of the grid. Many candidates chose “difficult” scales in order to spread the graph over the whole grid. Whilst this is a worthwhile objective it should not be done at the expense of unsuitable scaling. Thus using three large squares (30 mm) to represent 20 degrees gives a 1 mm square equivalent to 0.6667 degrees. This makes it very awkward for the candidates to accurately plot data and produces many plotting errors. A reasonable plot needs to have its points over at least half of the grid for both axes and preferably with a logical linear scale. Some chose to start the false origin on the temperature scale at 82.4 for the first graph which again caused plotting difficulties. For the first graph a temperature scale starting at 80 °C with 20 mm representing 10 degrees gives a perfectly adequate plot and a similar scale starting at 60 °C suffices for the second plot.

- (d) Many had “endothermic” presumably on the basis that the data in the table showed lower boiling temperatures. Unfortunately it seemed that most candidates misunderstood the data and referred to a “temperature decrease” rather than the correct and different “boiling temperature decrease”. Very few related the decrease in boiling temperature to the change in intermolecular forces of attraction. Some candidates ambiguously referred to “bonding” alone without specifying that as intermolecular.

There seemed to be a great deal of confusion between different intermolecular forces of attraction. Often covalent bonds were mentioned and only a few candidates appeared to understand what was happening with the intermolecular forces of attraction in the mixture. There was much confusion as to the type of intermolecular forces of attraction that different molecular structures produce.

Question 3

- (a) Many candidates made errors here. A common error was the lack of 2 decimal places on items of data where the zero is necessary, so that all the mass data are consistent (e.g. 4.80). Many found it difficult to give the correct answer of -0.30 since it is illogical, but it is the result of the data. Those candidates often wrote (+) 0.30, 0 or left it blank. Most candidates plotted accurately.
- (b) Most candidates read data from the graph correctly. A few inverted the two masses and a small number read the scales incorrectly.
- (c) The majority of candidates attempted this question and most had a reasonable calculation. The varieties of calculation methods seen were very wide and most were correct computations to the 1:1 ratio.
- (d) Virtually all of the candidates correctly gave loss of magnesium oxide which was encouraging since this answer could be successfully derived from the background given for the question.
- (e) If the experiment had been properly conducted then the final mass of 24.96 g should be more than the previous two masses, but it is less. An operational error such as not replacing the lid (or changing the lid) would be one way that this less mass could be found. Only those candidates who had thoroughly understood the data realised that and scored here.
- (f) Very few candidates realised that magnesium reacts with nitrogen (as well as oxygen) so missed the basic point of the question. A small number stated magnesium nitride was present but most answers centred on impurities in the magnesium or the crucible.

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Comments on specific questions

Question 1

- (a) The first mark for predicting and explaining how the boiling point would change with concentration proved to be a difficult opening question. While many candidates correctly predicted an increase in the boiling point with temperature only a small number were able to explain that in order to boil the vapour pressure of the solution must be equal to the ambient pressure and to achieve this an increased temperature is needed. Most candidates produced a sketch graph showing the increase in boiling point but where to place the 100°C mark proved to be much more challenging. Clearly, this mark should be at the starting point of the graph but many candidates were happy to place it elsewhere, some candidates even failing to give a value at all.
- (b) The mass of potassium chloride or the concentration of the potassium chloride solution was generally seen as the independent variable with the temperature or temperature change identified as the dependent variable. Occasionally these were reversed.
- (c) Many of the diagrams presented were over elaborate. The first mark was accessed by showing a simple apparatus, such as a beaker, containing water with some form of heating. Common errors included the use of a water bath and/or a sealed apparatus. On occasion, it looked as though the candidate was thinking of a standard enthalpy determination.

The correct positioning of the thermometer at the interface between the liquid and the vapour was shown only by a very small number of candidates.

Any thermometer range was acceptable (even 30°C to 3000°C) but to access the mark 100°C needed to be in the given range. Many thermometers had 100°C as the upper limit.

- (d) For the first mark, the listing/detail of the solutions to be used needed to clearly show that the allowed 100g mass of water was not exceeded while for the second mark at least five experiments were required. These two marks were accessible from any detailed information recorded in the table.

The final mark was for showing a correct molality calculation, which clearly showed both the correct M_r of the potassium chloride and 1000g as the mass of the water. Both here and in the table there was sometimes, inevitably, confusion between molality and molarity.

- (e) The hazard in this exercise is the hot/boiling water and/or the hot vapour. Common errors included reference to the Bunsen burner or the corrosive nature of the potassium chloride.

- (f) There were two acceptable limiting factors here. The possibility of solution saturation would clearly limit the range of the experiments while the limited supply of water would limit the number of feasible experiments.
- (g) There was a minimum of four column headings required to gain both of the marks available: - the mass/volume of water; the mass of potassium chloride; the boiling point (all three of these requiring an indication of the correct units) and the molality (here units were not required).

Common errors included the omission/incorrect use of units and the recording of initial and final temperatures rather than the boiling point. Here again candidates were perhaps thinking in terms of an enthalpy experiment.

Question 2

- (a) The two M_r s were generally correctly evaluated, the most common error being the omission of the water in the copper sulphate pentahydrate.
- (b) The calculations of the moles of the two substances were generally correct, with the use of erroneous M_r s being accepted. Occasionally errors were seen over the use of significant figures and incorrect column headings.
- (c) The fact that the sodium hydroxide was in excess was usually identified.
- (d) The quality of the graphical work was generally high with the most common error being the reversal of the axes. In their efforts to fully utilise the grid supplied, some candidates chose some very unusual scales. In many cases, these had a consequential effect on the quality of the plotting. Despite this, plotting showed a comfortable degree of accuracy. If the plotting was accurate, two anomalous points were revealed and the drawing of a line of best fit presented no real problem. Errors only occurred when the line was made up of two drawing attempts possibly arising from the use of a short ruler. In a number of cases, this produced a kinked line.
- (e) Most candidates were able to identify correctly the two expected anomalous points, although credit was given for any number of points not clearly on the drawn line that were correctly identified. The two anomalous points, one on each side of the line showed that either the amount of the hydroxide was larger than anticipated or less than anticipated. An excess mass could be explained simply by the precipitate not being fully dry, while a loss of some of the precipitate would explain the other anomaly. Some candidates failed to realise that merely weighing a smaller mass would produce a mass of precipitate in proportion and hence not be anomalous.
- (f) The three marks for this section were awarded from whatever graph the candidate had drawn and in general the slope measurements and calculation were accurate.

Depending on the juxtaposition of the axes, the calculated value of the slope was either 0.8 or 1.25. There were occasions however, where candidates used points from the table which were not on the drawn line.

- (g) This section was answered poorly with most candidates failing to score either of the two marks. Despite having obtained the correct slope in (f) most candidates were happy to accept either the 0.8 or 1.25 as supporting the 1:1 ratio shown in the equation.



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