

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

For this paper, the mean score was 20.9 (52.2%), well below the targeted value of 60%. The standard deviation of the scores was 6.64 (16.6%), indicating that overall the paper performed satisfactorily in distinguishing between the more able and less able candidates, but only 1.5% of candidates achieved a mark above 35 out of a possible 40.

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

Comments on Individual Questions

Two questions, **Questions 1** and **3**, had a high facility. **Question 1** involved the calculation of the relative atomic mass of an element from its isotopic abundance, and **Question 3** the pattern of first ionization energies of the Group IV elements.

Three questions had a low discrimination in distinguishing between more able and less able candidates. In **Question 13** 58% of candidates appreciated that SiCl_4 reacts with water to give a precipitate and an acidic

solution, but 27% thought it gave an acidic solution only.

Question 21 was a novel question in which the structure of 11-*cis* retinal, C₂₀H₂₈O, was described as possessing an aldehydic group and a cyclohexene ring. Whereas most candidates correctly appreciated the difference between *cis*- and *trans*-forms, when asked to deduce the number of carbon-carbon double bonds from its molecular formula, exactly the same proportion – 40% -- deduced incorrectly that there would be 6 as did those who gave the correct answer of 5. Presumably many of the former group did not appreciate that the formation of a ring system has the same effect on the C:H ratio of the molecular formula as does a double bond.

Question 31 was another novel question which proved much too challenging. If a 1 mol sample of a monomer was completely polymerized by addition polymerization, how many moles of polymer might, theoretically, be formed? No less than 83% of candidates thought that one possible answer was 1. That would mean that the polymer would have had the same number of molecules as did the starting material, which must therefore be identical to the monomer. The opposite extreme would be if all 6.02x10²³ molecules reacted to form a single chain polymer, and this would result in one molecule, but only 1/6.02x10²³ of a mole – only 26% appreciated that this could be an answer.

Two other questions, while performing satisfactorily, deserve comment.

Question 18 asked candidates to state which three car exhaust gases are removed by a three-way catalytic converter. 40% of candidates correctly identified carbon monoxide, hydrocarbons and nitrogen oxides as the gases, but a greater number, 46%, thought sulfur dioxide was removed and not hydrocarbons.

Question 29 asked candidates to identify the bromoalkane which could be treated first with alcoholic sodium cyanide and then undergo acidic hydrolysis to give a specified carboxylic acid. 24% of candidates obtained the correct answer, but 54% chose a structure which would have had an additional –CH₂– group in the alpha-position to the carboxylic group.

References are given to the Learning Outcomes within each section of the Syllabus

Item Number	Learning Outcome	Item Number	Learning Outcome
1	1(d)	21	1(i); 10.1(f)
2	1(f)	22	10.1(g)
3	2(i)(ii),(iii); 9.1(l); 9.2(d)	23	10.2(d)(iv); 10.3(a); 10.8(a)
4	3(f)	24	10.2(d)(i)
5	3(h),(i)	25	10.1(b)(iii),(iv); 10.2(e)
6	5(e)(i)	26	10.2(c)
7	6(a)	27	10.2(d)(i); 10.5(a),(c),(d)
8	7(c)	28	10.5(b)
9	3(f); 7(b)	29	10.3(a)(i); 10.6(a)
10	5(a),(f); 8(a)	30	10.6(h)
11	6(a); 8(e)(i)	31	1(b); 10.8(a)
12	9.1(a)	32	3(g),(k); 4(e)(iv)
13	9.1(i)	33	7(d)
14	9.1(g),(h),(i)	34	8(a),(d)
15	9.4(a),(b),(e)(ii)	35	9.2(f); 9.6(b)(ii)
16	9.4(g)	36	9.4(f)(ii)
17	7(b),(d); 8(c),(e); 9.6(j)	37	10.3(b)
18	9.6(f); 10.2(i)	38	2(f); 10.2(c); 10.3(e)
19	1(g); 9.6(b)(i)	39	10.2(g); 10.4(a)(iv),(v)
20	10.1(g),(i)	40	10.1(a)(iii),(iv); 10.4(b); 10.5

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Paper 9701/12
Multiple Choice

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

General Comments

For this paper, the mean score was 22.6 (56.5%), slightly below the targeted value of 60%. The standard deviation of the scores was 6.94 (17.4%), indicating that overall the paper performed satisfactorily in distinguishing between the more able and less able candidates, but only 1.7% of candidates achieved a mark above 35 out of a possible 40.

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

Comments on Individual Questions

Two questions, **Questions 2** and **30**, had a high facility. **Question 2** involved the pattern of first ionization energies of the Group IV elements, and **Question 30** the calculation of the relative atomic mass of an element from its isotopic abundance.

Four questions had a low discrimination in distinguishing between more able and less able candidates.

In **Question 12** 60% of candidates appreciated that SiCl_4 reacts with water to give a precipitate and an acidic solution, but 26% thought it gave an acidic solution only.

Question 20 was a novel question in which the structure of 11-*cis* retinal, $\text{C}_{20}\text{H}_{28}\text{O}$, was described as possessing an aldehydic group and a cyclohexene ring. Whereas most candidates correctly appreciated the difference between *cis*- and *trans*-forms, when asked to deduce the number of carbon-carbon double bonds from its molecular formula, whereas 39% correctly deduced that there were 5, 43% deduced incorrectly that there would be 6. Presumably many of the latter group did not appreciate that the formation of a ring system has the same effect on the C:H ratio of the molecular formula as does a double bond.

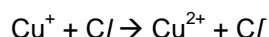
Although 42% of candidates correctly identified the correct answer, **C**, in **Question 27**, this question was intentionally a more penetrating one, and it was therefore not surprising that there was a wide choice of answers. The question asked candidates to identify the product of the attack by the anion $\text{CH}_2\text{CO}_2\text{CH}_3^-$, behaving in a parallel manner to a CN^- ion in adding to an aldehyde. 24% of candidates chose option **B**, in which the carboxylic group had the reverse orientation for it to be a possible answer.

Question 35 was concerned with the action of concentrated sulfuric acid on solid sodium bromide. Although 55% of candidates identified the correct combination of answers in this multiple choice item, it did give rise to some surprising results in an area of the syllabus that is usually very well understood. 45% of candidates thought that sulfuric acid is *oxidised* to sulfur dioxide, and 31% that bromide ions are *reduced* to bromine.

Question 40 was another novel question which proved much too challenging. If a 1 mol sample of a monomer was completely polymerized by addition polymerization, how many moles of polymer might, theoretically, be formed? No less than 80% of candidates thought that one possible answer was 1. That would mean that the polymer would have had the same number of molecules as did the starting material, which must therefore be identical to the monomer. The opposite extreme would be if all 6.02×10^{23} molecules reacted to form a single chain polymer, and this would result in one molecule, but only $1/6.02 \times 10^{23}$ of a mole – only 30% appreciated that this could be an answer.

Two other questions deserve comment.

Question 10 was about photochromic glass which darkens in the presence of light because of the production of silver atoms from silver salts, but will become more transparent again when the source of light is removed. There are three simple reactions involved, and these were given. 40% of candidates correctly deduced that Cu^+ and Cu^{2+} ions, present in the glass, act as catalysts in redox reactions, but 34%, including some of the more able candidates, rather surprisingly thought that the reaction



is the one in which light is absorbed – despite the fact that it does not involve any silver atoms.

Question 28 asked candidates to identify the bromoalkane which could be treated first with alcoholic sodium cyanide and then undergo acidic hydrolysis to give a specified carboxylic acid. 26% of candidates obtained the correct answer, but 56% chose a structure which would have had an additional $-\text{CH}_2-$ group in the alpha-position to the carboxylic group.

Cambridge International Advanced Level
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Principal Examiner Report for Teachers

References are given to the Learning Outcomes within each section of the Syllabus

<i>Item Number</i>	<i>Learning Outcome</i>	<i>Item Number</i>	<i>Learning Outcome</i>
1	1(f)	21	10.1(g)
2	2(i)(ii),(iii); 9.1(l); 9.2(d)	22	10.2(d)(iv); 10.3(a); 10.8(a)
3	3(f)	23	10.2(d)(i)
4	3(h),(i)	24	10.1(b)(iii),(iv); 10.2(e)
5	5(e)(i)	25	10.2(c)
6	6(a)	26	10.2(d)(i); 10.5(a),(c),(d)
7	7(c)	27	10.5(b)
8	3(f); 7(b)	28	10.3(a)(i); 10.6(a)
9	5(a),(f); 8(a)	29	10.6(h)
10	6(a); 8(e)(i)	30	1(d)
11	9.1(a)	31	3(g),(k); 4(e)(iv)
12	9.1(i)	32	7(d)
13	9.1(g),(h),(i)	33	8(a),(d)
14	9.4(a),(b),(e)(ii)	34	9.2(f); 9.6(b)(ii)
15	9.4(g)	35	9.4(f)(ii)
16	7(b),(d); 8(c),(e); 9.6(j)	36	10.3(b)
17	9.6(f); 10.2(i)	37	2(f); 10.2(c); 10.3(e)
18	1(g); 9.6(b)(i)	38	10.2(g); 10.4(a)(iv),(v)
19	10.1(g),(i)	39	10.1(a)(iii),(iv); 10.4(b); 10.5
20	1(i); 10.1(f)	40	1(b); 10.8(a)

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Paper 9701/21

AS Structured Questions

General comments

There were many excellent answers to each of the individual questions, but only a relatively small number of candidates scored high marks on all five questions.

Answers to **Questions 1** and **2** were generally sound while answers to **Questions 3(b)** and **4** showed a welcome increase in the level of knowledge of organic chemistry compared to recent examinations.

However, **Questions 3(a)**, **3(c)** and **5** were often poorly done. Many candidates experienced difficulties with the calculations in **Question 3**.

Centres are asked to remind candidates of the need to present their work clearly. On this paper, 'methanal' was a correct answer. On occasion, Examiners were unable to distinguish between 'methanal' and 'methanol'. If an answer cannot be read, no marks can be awarded.

Comments on specific questions

Question 1

There were many good answers to this question which tested candidates' understanding of some fundamental concepts of AS level chemistry.

- (a) This was generally well answered with the majority of candidates giving a clear explanation.
- (b) Most candidates correctly calculated A_r of magnesium to be 24.33. A small number of candidates failed to give their answer to four significant figures and were penalised. Some candidates clearly thought that 'four significant figures' referred to the number of decimal places to be used and gave their answer as 24.3269 and they too were penalised.

Other candidates 'rounded off' their answers in the early stages of their calculation and gave answers such as 24.37 which Examiners did not accept.

A number of candidates used the sum of the isotopic masses as the denominator instead of 100.

- (c) Almost all candidates correctly calculated the atomic structures of the two isotopes given.

isotopes	number of		
	protons	neutrons	electrons
^{226}Ra	88	138	88
^{238}U	92	146	92

- (d)(i) The correct answer, Ra^{2+} , was given by almost all candidates.
- (ii) Fewer candidates were able to give a clear and correct statement to this part. Many gave an answer for the formation of Ra^+ rather than Ra^{2+} or of Ra^{2+} from Ra^+ . Candidates were expected to use the *Data Booklet* and see the trend in the ionisation energies (IEs) of the Group II elements. This would lead to a value that was less than $(502 + 966) \text{ kJ mol}^{-1}$, and Examiners accepted answers in the range 1000 to 1400 kJ mol^{-1} . Often the candidate's stated value of IE for $\text{Ra}(\text{g})$ to $\text{Ra}^{2+}(\text{g})$ was incorrect; however, the explanation that IEs decrease down the group or that there is increased shielding down the group was frequently given credit where appropriate.

Question 2

Question 2 tested candidates' knowledge and understanding of the reactions of Group II metals. While there were many good answers, there were also many responses that showed that candidates had neither carried out the reactions of magnesium with water and steam, nor seen them performed.

- (a) (i)** Most candidates answered this correctly.
- (ii)** Examiners expected candidates to use their knowledge of Group II compounds to state that radium carbonate would be insoluble.
- (b)** While many candidates gave two correct half equations, there was a significant number who copied out the half equations from the *Data Booklet* and, by including an equilibrium sign, failed to make it clear in which direction each electrode reaction would proceed. Examiners agreed that they would not give such answers full credit.
- (c) (i)** Some of the descriptions of the reaction of magnesium with water were very poor and suggest that this simple reaction has not been carried out by many candidates. Many candidates failed to state what would be seen during the actual reaction, giving instead a statement of what would be formed.
- (ii)** This part was also badly answered with many candidates again failing to state what would actually be observed. Examples of this were statements such as when steam is passed over heated magnesium, 'hydrogen gas can be seen' or that 'a gas is evolved that pops with a lighted splint'.
- (d) (i)** A surprising number of candidates failed to give the correct products or gave an unbalanced equation in this part.
- (ii)** This part was quite well answered, with many candidates correctly deducing what would be observed.
- (iii)** The majority of candidates correctly predicted that the pH of the solution formed would be greater than 10.
- (iv)** This was less well answered. Some candidates contradicted themselves by saying that the reaction with radium would be less vigorous than with barium and then explaining why it would be more vigorous than with barium.

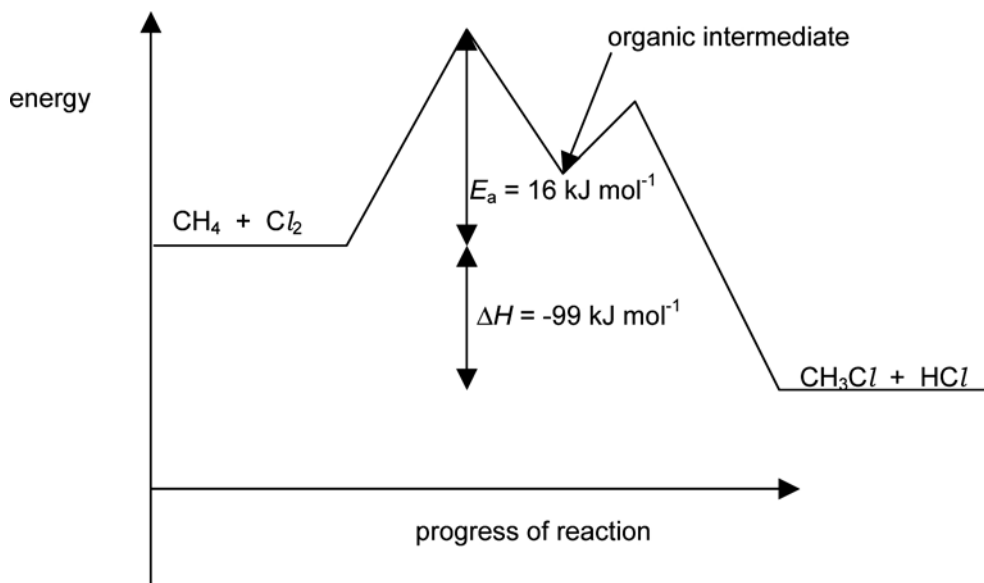
Question 3

In this question, many candidates spoiled their answers by making simple arithmetical errors in their calculations, or by failing to give equations in part **(b)(i)** as the question required.

- (a) (i)** This part of the question required candidates to use the data given in the question to calculate $\Delta H_{\text{reaction}}^{\ominus}$ for the formation of CH_3Cl .
- The majority of candidates correctly calculated $\Delta H_{\text{reaction}}^{\ominus}$ to be -99 kJ mol^{-1} .
- A small number were penalised for not using all of the data in the question or for using bond energy data from the *Data Booklet*.
- (ii)** In this part, candidates were expected to extract and use the relevant bond energy data from the *Data Booklet*. Some candidates were unable to quote the correct values, particularly for the I-I bond, and were penalised.
- The correct answer is $+22 \text{ kJ mol}^{-1}$.
- (iii)** Since the theoretical value of $\Delta H_{\text{reaction}}^{\ominus}$ for the reaction is small and positive, and the reaction does not, in fact, occur, the activation energy must be high. Relatively few candidates were able to deduce this.

- (b)(i) Knowledge of the free radical mechanism of the chlorination of methane was generally sound but many candidates lost marks by not giving equations to support their descriptions. A small number also lost marks by not giving both equations of the propagation step.
- (ii) Few candidates were able to state clearly that the organic intermediate would be the methyl radical, $\cdot\text{CH}_3$.
- (c) Examiners saw very few fully correct reaction pathway diagrams. Many candidates lost marks because they did not indicate on their sketch 'the relevant energy changes and their values'.

Few realised that the diagram consists of two 'humps' as shown below, i.e. with the second 'hump' lower than the first and the organic intermediate in the trough between them.



Question 4

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

- (a)(i) Most candidates correctly gave the empirical formula of compound E as $\text{C}_2\text{H}_5\text{O}$. However, a significant number of candidates gave as their answer the molecular formula, $\text{C}_4\text{H}_{10}\text{O}_2$, rather than the empirical formula.
- (ii) Only a minority of candidates gave the correct skeletal formula of compound D which is given below.



Section 10.1 of the Syllabus contains important information about structural, displayed and skeletal formulae.

- (iii) Many candidates struggled with this part. Compound A displays geometrical or *cis-trans* isomerism while compound D is chiral. A significant number gave incorrect answers in which one compound was described as having 'cis isomerism' and a completely different compound as having 'trans isomerism'.

- (b)(i) The majority of candidates correctly described this reaction as 'elimination' or 'dehydration'. A small number of candidates gave answers such as 'elimination or reduction' and were penalised. Examiners do not give any credit for such contradictory responses.
- (ii) This was generally well answered. Those candidates who chose sulfuric acid as their dehydrating agent were only given credit if they stated that the acid must be 'concentrated'. A number of candidates gave phosphoric acid as the reagent, confusing their answer with 4(c).
- (iii) A pleasing number of candidates deduced that two molecules of water would be removed for the molecule of compound E to give buta-1,3-diene, $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$, although those candidates who attempted to name the compound often omitted the 'diene' part of the name and were penalised.
- (c)(i) Most candidates understood that the reaction involved the addition of a water molecule to the alkene to form butan-2-ol.
- (ii) However, fewer candidates were able to outline how this reaction would be carried out often giving water as the reagent instead of steam (when using phosphoric acid) or adding water before the concentrated H_2SO_4 .
- (iii) While many candidates correctly stated that acidified potassium dichromate(VI) would be used for the oxidation, a significant number omitted to state that the dichromate(VI) must be in acid solution and were penalised.
- (d) This was correctly answered by the majority of candidates.

Question 5

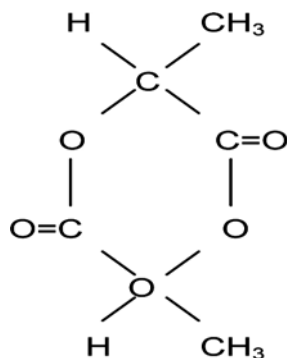
The last question on the paper required candidates to apply their knowledge and understanding to three different compounds with the same empirical formula. As with **Question 4**, many candidates struggled with parts of this question. A significant number of candidates gave ambiguous answers when they tried to identify some of the compounds. Examiners expected candidates to give a structural formula but were prepared to accept a correct name.

- (a) Compound **G** was identified by the majority of candidates as methanal, HCHO .
- (b)(i) Most candidates correctly stated the functional group to be $-\text{CO}_2\text{H}$ or carboxylic acid. Examiners did not accept the simple answer 'acid'.
- (ii) Fewer candidates correctly identified **H** as ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$.
- (iii) This part was poorly done. Compound **J** must be a hydroxyacid and **only** $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$ will give the reactions in part (c).
- (c) Relatively few candidates gave correct answers to this part.

The oxidation of $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$ by heating under reflux with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ will give compound **K**, $\text{CH}_3\text{COCO}_2\text{H}$, which will, in turn, react with 2,4-dinitrophenylhydrazine.

A significant number of candidates gave the isomer of compound **J**, 3-hydroxypropanoic acid, $\text{HOCH}_2\text{CH}_2\text{CO}_2\text{H}$. When oxidised by heating under reflux with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ this would give $\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$ which will **not** react with 2,4-dinitrophenylhydrazine.

- (d)(i) Compound **J** contains an alcohol group and a carboxylic acid group. When alcohols and carboxylic acids are warmed with concentrated sulfuric acid, esters are formed. In the case of compound **J**, the cyclic compound **L**, would be formed.



compound **L**

Those candidates who deduced this structure are to be congratulated.

- (ii) From different pieces of information in the question candidates were able to deduce that the formation of compound **L** could be described as esterification, dehydration, elimination or condensation. Examiners accepted any of these answers which many candidates obtained independently of their answers to part (i).

CHEMISTRY

<p>Paper 9701/22 AS Structured Questions</p>
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General comments

There were many excellent answers to each of the individual questions, but only a small number of candidates scored high marks on all five questions.

Answers to **Questions 4** and **5** showed a welcome increase in the level of knowledge of organic chemistry compared to recent examinations.

However, **Questions 1** and **3** were often poorly done. Many candidates had limited knowledge of the bonding and structure of SiO_2 in **Question 1**, and a significant number experienced difficulties with the equations and calculations in **Question 3**.

Centers are asked to remind candidates of the need to present their work clearly. If an answer cannot be read, no marks can be awarded.

Comments on specific questions

Question 1

This question tested candidates' knowledge of the structure of SiO_2 and of the basic assumptions of the kinetic theory as applied to an ideal gas. Each of these topics is specifically mentioned in **section 4** of the Syllabus. Despite this, many candidates showed rather poor knowledge or gave contradictory answers.

- (a) Examiners expected candidates to describe CO_2 as a simple molecular compound with weak van der Waals' forces between the molecules, and SiO_2 as giant molecular with strong covalent bonds. Many candidates wrongly thought that SiO_2 had strong intermolecular forces or that CO_2 had weak covalent bonds.
- (b) Examiners looked for an SiO_4 unit together with an Si-O-Si bond as the minimum to gain credit. Many answers, however, had errors such as double bonds, Si-Si bonds or oxygen atoms with three bonds attached.
- (c) (i) Many candidates were able to give at least three correct statements.
- Some candidates lost marks by making incomplete statements such as "the gas has no volume" rather than "the molecules of the gas have no volume". Examiners did not accept any reference to the ideal gas equation $pV=nRT$.
- (ii) Relatively few candidates were able to explain that in CO_2 there are intermolecular forces, or that molecules have a definite volume.
- (d) Examiners were looking for the fact that graphite has delocalised electrons. Some candidates thought graphite conducts because it contains ions.
- (e) (i) At the temperature given in the question the products would be SiC and CO_2 . A large number of candidates offered an equation with oxygen gas as a product.
- (ii) Examiners expected candidates to link the description of SiC as a hard material to the similarity with diamond.

Question 2

The study of the chemistry of the chlorides of the period three elements is an important part of inorganic chemistry at AS level. Many candidates gave good answers to this section of the question although others struggled. There were also many pleasing answers to the questions about hydrides, many candidates showing a good ability to apply their knowledge to unfamiliar compounds.

- (a) (i) Oxidation numbers should have a sign followed by a number; the sign was sometimes not given.
- (ii) A significant number of candidates struggled with this part which is specifically mentioned in **sections 9.1(f) and (j)**, of the Syllabus.

For Na to Al, Examiners were expecting candidates to describe the loss of electrons to give the noble gas configuration of Ne. For Si to S, on the other hand, they expected candidates to describe the sharing of electrons to give the noble gas configuration of Ar.

- (b) This was generally well answered with good descriptions of the structure of the NaCl crystal being offered. However some candidates, having correctly specified ionic bonding for NaH in (ii), produced a covalent 'dot-and-cross' answer in (iv).
- (c) This was also well answered although some candidates had the pH of aluminium chloride above the accepted range of 1 to 4.
- (d) (i) Some candidates clearly confuse structure and bonding. 'Molecular' was not accepted as the type of bonding in SCl_2 because it is a simple molecular compound with covalent bonding.
- (ii) An encouraging number of candidates produced a correct equation in this part.

Question 3

Chemistry is an experimental science and candidates at AS and A levels are expected to carry out a significant amount of experimental work themselves. This question was intended to test their understanding of the important processes in a standard organic preparation.

- (a) The large majority of candidates did not appreciate that the equation for the reaction between NaBr and H_2SO_4 was required for stage I; however, the stage II equation was generally well answered.
- (b) Many candidates correctly calculated the number of moles used of the reactants NaBr and C_4H_9OH . Errors were often due to incorrect values of relative molecular masses being calculated. To gain any credit, candidates had to calculate both M_r values, as shown below.

$$n(\text{NaBr}) = n(\text{HBr}) = \frac{35}{103} = 0.34$$

$$n(\text{C}_4\text{H}_9\text{OH}) = \frac{20}{74} = 0.27$$

- (c) This calculation was less well done. A significant number of candidates did not realise they had to use 15.4 g of butanol to calculate the maximum yield of bromobutane as 28.5 g or 0.208 mol and then compare this answer with the actual yield of 22.5 g or 0.164 mol to give a yield of 79%.
- (d) There were relatively few candidates who answered this part completely correctly. Examiners hoped to see Br_2 or SO_2 as the inorganic by-products due to the oxidising nature of concentrated sulfuric acid. But-1-ene or dibutylether were accepted as the organic by-product due the dehydrating nature of the concentrated acid.

Question 4

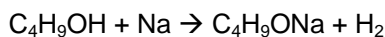
This question tested candidates' knowledge of simple organic reactions. There were many very good answers.

- (a) This was well answered. A common error was giving **Y** as an aldehyde, even though it was produced by heating **W** under reflux. A less common error was giving **Z** as a diol, although hot, concentrated, rather than cold dilute acidified manganate(VII), was reacted with **X**.
- (b) The alkene was usually identified correctly in (i), but many polymers in (ii) contained double bonds.

Question 5

This question tested candidates' ability to use their knowledge and understanding of organic chemistry when applied to unusual compounds. There were many very good answers.

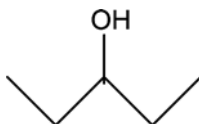
- (a) Most candidates knew the correct reagent to be 2,4-dinitrophenylhydrazine, but a significant number thought Tollens' reagent reacted with propanone.
- (b) Many candidates knew they would see a gas given off, but many otherwise correct equations were unbalanced, the most common error being in the number of moles of hydrogen as in the following, unbalanced, equation.



- (c) There were many correct answers here, but a number of candidates are still unsure of the differences between structural, displayed and skeletal formulae for organic compounds. These are outlined in Syllabus **section 10.1**.

Candidates were penalised if the O of the -OH group was not clearly bonded to a carbon atom.

In part (iii), the accepted skeletal formula was as follows.



- (d) The alcohol was pentan-2-ol, so the structural formulae of pent-1-ene and pent-2-ene were required.
- (e) (i) This required candidates to deduce the structure of an alcohol with the longest carbon chain containing three carbon atoms i.e. $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}_2\text{OH}$.
- (ii) The oxidation of this alcohol under the conditions given produced the corresponding carboxylic acid, $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CO}_2\text{H}$.

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Paper 9701/31

Advanced Practical Skills 1

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 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 Centres do provide the Supervisor data for multiple sessions/laboratories but without seating plans or candidate lists and there is insufficient data to place candidates within each Session. Candidates in these Centres may again be disadvantaged.

The paper was accessible to the majority of candidates and produced a wide range of marks. There was little evidence of candidates failing to finish the paper in the allocated time.

Comments on specific questions

Question 1

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

- (a) Most candidates recorded the mass of the (weighing bottle + zinc powder), the mass of the (bottle + residue) after tipping the zinc powder into the copper sulfate and the mass of the zinc powder used in the experiment. Any error in subtraction entailed a penalty in the calculation – part (e).
- (b) Candidates were instructed to read through the practical instructions before commencing any practical work. Those who did this carefully were able to prepare a table of results in advance of the experiment and display clearly the times when temperature readings were taken, the point at which zinc powder was added and the times when temperatures were not taken. The Examiners were looking for a single table, covering both experiments and showing time intervals of half a minute. Some candidates did not record the temperatures for the initial two minute "steady" period, others added zinc at a $\frac{1}{2}$ minute interval and many candidates did not continue cooling for five minutes after the maximum temperature was recorded.

The Examiners would encourage preparation of a table for the results in the following form.

time / min	temperature / °C	
	experiment 1	experiment 2
0		
0.5		
1		
1.5		
2		
2.5		
3	<i>(add Zn)</i>	<i>(add Zn)</i>
3.5		
4		
4.5		
5		
5.5		
6		
6.5		
7		
7.5		
8		

Errors frequently seen in the table included the following.

Two separate tables drawn.

The time of addition of zinc and the timing at which the next temperature reading was taken was often uncertain from the recorded results.

Units mixed, e.g. 1.30 (1 minute 30 seconds), for 1.5 minutes.

Temperatures not recorded to the nearest 0.5 °C. Some candidates claimed to be able to read a 1 °C scale to 0.2 °C or better; others gave no decimal place at all. Given the number of temperature readings to be recorded the Examiners expected to see some temperature readings ending with .0 °C, others with 0.5 °C.

“Quality” marks were assessed by comparing the temperature rise against the experimental temperature rise obtained by the Supervisor and for comparing the time interval between adding the zinc powder and obtaining the maximum temperature rise. This was assessed for each experiment. Most candidates scored at least half of the “Quality” marks available.

A very small number of candidates appeared to be unable to read a thermometer correctly – recording all temperatures reduced by a factor of 10; e.g. 25 °C was recorded as 2.5 °C. Where it was obvious that this had been done consistently Examiners assessed the “Quality” marks on the “correct” temperature rise.

(c) Graph

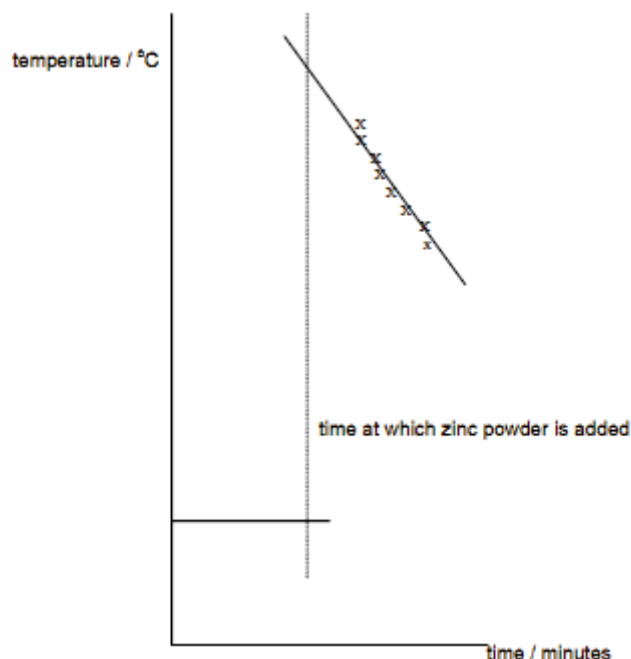
As previously mentioned the Examiners were disappointed with the quality of a large number of the graphs seen.

Some candidates failed to clearly label at least one *x*-axis and one *y*-axis, the minimum requirement for the first mark in the section.

Many candidates did not consider carefully the suitability of the adopted scales. Some were unable to plot the initial temperature of the copper sulfate solution; others could not include all temperatures after the zinc was added and others did not follow the instruction to extend the temperature scale to 10 °C above the highest temperature recorded.

Many candidates did not appreciate the nature of the graph that had to be drawn and did not attempt to extrapolate the cooling curve to the time of mixing.





Where there is a considerable temperature change on mixing reagents, candidates should be aware of this technique for estimating the temperature rise at the actual point of mixing the reagents, allowing for any heat loss or gain in the apparatus.

- (d) Many candidates read the intercept correctly but gave the theoretical maximum temperature rather than the temperature rise.

Calculations

The majority of candidates showed working in each step of the calculation attempted. The number of significant figures appropriate to each answer was generally ill considered. Most candidates failed at the first step, calculating 0.02 mol of CuSO_4 pipetted into the cup. The concentration of the copper sulfate solution had been given as 0.80 mol dm^{-3} therefore Examiners were looking for 0.020 mol of CuSO_4 in (e). Many candidates also failed to note that the final answer to (h) was required correct to 3 significant figures.

- (e) The moles of CuSO_4 and Zn used in each experiment were generally correctly calculated.
- (f) Most candidates were able to use their answers to (e) to determine which of the reagents was in excess. Many candidates were not awarded the mark in this section however, as they did not make reference to the mole ratio shown in the equation.
- (g) More able candidates correctly calculated the heat energy released during the experiment – a maximum temperature rather than temperature rise given in (d) was treated as an error carried forward in this section. Most candidates gave the correct unit for their calculated value. Weaker candidates often used the mass of zinc in the expression – on its own or combined with the mass of the solution.
- (h) Most candidates correctly divided their answer to (g) by the reagent not in excess (from (f)) but many failed to give a negative sign for the ΔH value.
- (i) Heat loss or precision of the thermometer used were the most common acceptable errors given. Weaker candidates often gave vague answers referring to errors in timing, problems through stirring or parallax errors. The Examiners have noted over a series of examinations the frequent and inappropriate reference to parallax errors.

- (j) The rubric to the question made it clear that the improvement to experimental method in (j) had to minimise the error given in (i). Many candidates who had “vague” answers in (i) mentioned heat loss for the first time in (j) and a way of minimising the heat loss. Unfortunately they were not answering the question. It was very common to score either both marks or no marks taking **sections (i) and (j)** together.

Question 2

- (a) The Examiners do not expect essays to be written for observations but they do expect all changes noticed during careful observation to be recorded.
When heating copper(II) carbonate the following should have been observed.

A green/blue solid turning black

Candidates should have noticed that the solid behaved like a liquid in the boiling-tube (fluidity) and this should have led to the conclusion that a gas was being released, a gas which had to be tested.

The second mark in the section was for describing a suitable test on the gas. The Examiners considered that the only colourless gases likely to be released on heating a solid were carbon dioxide, oxygen and ammonia. A suitable test for any of these gases gained the second mark (regardless of the result of the test).

The mark for testing a gas was also available as a retrospective mark in (b) on adding the solids to nitric acid, but now the only acceptable test was that for carbon dioxide with limewater.

Many candidates missed one of the colours or the physical state and failed to record that gas was being given off on heating.

- (b) Candidates were instructed to dissolve the solids in a minimum of dilute nitric acid. Many candidates recorded that one or more did not dissolve in the acid, they had clearly used insufficient acid – all nitrates being soluble in aqueous solution. The colours of the solutions formed were required. Two common errors seen in observations were (i) to describe a colourless solution as a clear solution or (ii) to describe the contents of a tube as a white solution.

Clear is not acceptable as a colour – $\text{CuSO}_4(\text{aq})$ which is blue in colour is a clear solution. An object held behind the tube containing the copper sulfate solution is clearly visible, this is the meaning of a clear solution. If a solution appears to be white it contains suspended solid or is an emulsion formed from two immiscible liquids – there are no white solutions.

Many candidates recorded effervescence with one or more of the **FA** coded chemicals but failed to carry out any test to identify the gas evolved.

- (c) Many candidates identified carbonate as the anion present from the effervescence seen in (b). In giving an explanation the Examiners expected candidates to refer to a specific reaction.

- (d) The results of the tests with aqueous sodium hydroxide and aqueous ammonia were generally well presented. Most candidates reported the effect of adding the reagent to excess when a precipitate was observed on first addition of the reagent. The most common missed observation was with **FA 3**, where the initial white to buff precipitate turned brown on standing. Centres should note from the published mark scheme that the criterion for observation marks is often more demanding than that for the conclusions.

Many candidates gave one cation for each of the solutions – ignoring the rubric that stated that a single cation could be identified for two of the solutions and a pair of cations for the remaining solution.

- (e) Where any pair of cations was given for one solution in (d), one mark was given for suggesting a reagent that would correctly distinguish between the named ions.

A second mark was given for an observed reaction that matched the reaction of the selected reagent with $\text{Pb}^{2+}(\text{aq})$, the ion expected to be identified in this section.

Centres and candidates are reminded again that reagents do not consist of single ions, e.g. potassium iodide is a reagent; iodide is not a reagent.

- (f) This part of the question was unusual in that there should have been no reaction in the majority of the tests. In practice observation/deduction exercises, candidates should be reminded that important conclusions can be drawn from “negative tests”, i.e. the absence of any change on adding a specific reagent.

For a conclusion the Examiners allowed either the presence of a sulfate in **FA 3** from the reaction with barium nitrate and nitric acid **or** the absence of any halide from the reaction with silver nitrate.

A small number of the more able candidates had all recorded observations as expected and made both conclusions.

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<p>Paper 9701/32 Advanced Practical Skills 2</p>
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General comments

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

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and to a corresponding set of Supervisor results. Regrettably a number of Centres continue to provide no Supervisor information.

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

Some Centres do provide the Supervisor data for multiple sessions/laboratories but without seating plans or candidate lists and there is insufficient data to place candidates within each Session. Candidates in these Centres may again be disadvantaged.

The paper was accessible to the majority of candidates and produced a good distribution of marks. There was little evidence of candidates failing to finish the paper in the allocated time.

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 very disappointing.

- (a) Most candidates recorded the mass of the boiling tube, the mass of the boiling tube + potassium nitrate and the mass of potassium nitrate used in the experiment. Any error in subtraction entailed a penalty in part (d). Most candidates tabulated results with appropriate headings and units and recorded weights with consistent precision.

Centres were required to provide each candidate with 20.0 g \pm 0.2 g of potassium nitrate. It was clear from the masses recorded that some Centres did not follow this instruction and provided a greater mass of the solid which had an effect on the "quality" marks awarded.

Many candidates did not follow the instructions given for the experiment – to tip all of the solid into the weighed boiling-tube. Again, use of a small quantity of the solid provided had an effect on the "quality" marks awarded.

- (c) The following were among the common errors seen in the recorded results.
- (i) The total volume of distilled water was not recorded with sufficient precision – Examiners were expecting to see 14.00 cm³, 16.00 cm³ etc. as water was added from a burette.

- (ii) Temperatures were not recorded to the nearest 0.5 °C. Integral temperatures were very common and temperatures recorded to 2 decimal places were also seen but far less common. In the final sentence of this section candidates were reminded to consider the precision of the apparatus being used.

Where approximately 20 g of solid had been weighed and dissolved the temperatures at which crystals formed gave fairly good agreement with the Supervisor results recorded for 14.00 cm³ and 16.00 cm³ of water and “Quality” marks were awarded.

- (d) Most candidates were able to use the formula provided to calculate the solubility of potassium nitrate for each of the four different temperatures obtained in the experiment. Two marks were awarded for correct calculation of all four values and a further mark for giving answers to 3 or 4 significant figures. Some candidates lost one or both of the first two marks for incorrect rounding for the significant figures given in their answers.

(e) **Graph**

As previously mentioned the Examiners were disappointed with the quality of a large number of the graphs seen.

A small but significant number of candidates plotted temperature against solubility instead of solubility against temperature. All candidates should appreciate the significance of the “order” given in the question.

Many candidates did not consider carefully the suitability of their scales. They had to consider the 4 experimental points and the need to read the solubility from the graph at 42.5 °C. Candidates who were not awarded the first mark because of poor scale selection often had plotted points that were “bunched” in one small area of the graph paper. Candidates who took no note of the instruction **not** to start either scale at zero were likely to be included in this group.

The Examiners were looking for easy to read/use scales. If a calculator had to be used to calculate the number of small squares from a reference point on the scale, the second mark was not awarded. The Examiners checked each point that could be plotted from the data in (d) – even if this entailed calculation as above. It was very common to find that at least one of the four points had been plotted incorrectly. Points that should have been on a line of the graph paper were off the line and vice versa. Values such as 100.3 were frequently plotted as 103. The poor quality of plotting led the Examiners to question if the plotting of experimental results is a commonly practised technique.

Most candidates were able to draw a straight line or curve that bore a reasonable relationship to the plotted points but far fewer candidates were able to draw anything approaching a “best-fit” line. Where appropriate scales had been chosen candidates were able to read from the graph the solubility at 42.5 °C.

- (f) Most candidates were able to say that solubility increased with increasing temperature but a statement to the effect that “solubility increases with temperature” was considered too imprecise for the award of the mark – the Examiners needed to know if the temperature was increasing or decreasing.
- (g) The majority of candidates correctly stated that the dissolving **FB 1** was endothermic and gained the first mark. To gain the second mark they needed to refer to heat/energy being absorbed in dissolving the solid or to the equilibrium shifting to the right as temperature increases. A temperature increase favouring the forward reaction was considered insufficient for the award of the second mark being little more than a repeat of the information already given in (f).
- (h) Comparatively few candidates were able to suggest two possible sources of inaccuracy. The most commonly seen acceptable answer referred to the difficulty in identifying the formation of the first crystals in the solution. Other acceptable answers seen were (i) evaporation of some of the water in the solution, (ii) the time delay in noticing the crystals and reading the thermometer and (iii) the formation of solid on the thermometer or on the inner wall of the boiling-tube during the experiment. Weaker candidates frequently referred to errors in weighing, changing room temperature or parallax errors.

The Examiners have noted over a series of examinations the frequent and inappropriate reference to parallax errors.

Candidates were asked to suggest possible sources of error **other than** poor experimental technique. Many answers did fall into the category of poor experimental technique.

- (i) This proved to be an extremely difficult part of the question with a minority of candidates scoring either mark. The Examiners are at a loss to explain why the question was so difficult but note that most candidates who did make an attempt at an answer started with solid potassium nitrate and water; and described the production of a saturated solution or described a method similar to that already performed. The question clearly stated that a saturated solution can be prepared in a water bath at 60 °C, and if the mass of solution and solid dissolved in that solution can be found the solubility can be determined. The Examiners were looking for the following simple steps.

1. Weigh a container
2. Weigh the container + solution saturated at 60 °C
3. Evaporate the water in the solution.
4. Weigh the container + solid.

A small number of candidates attempted to give an expression for calculating the solubility but the majority of these **incorrectly** gave the solubility as

$$\frac{\text{mass of solid}}{\text{mass of **solution**}} \times 100$$

Question 2

- (a) Candidates were instructed to dissolve the solids in a minimum of dilute hydrochloric acid, warming each solid with the acid. Many candidates recorded that one or more did not dissolve in the acid, they had clearly used insufficient acid candidates had been told that each of the solids contained either a sulfite or a sulfate and should have observed bubbles of gas (SO₂) evolved with two of the solutions. It was expected that candidates, having observed the evolution of gas, would make an appropriate test on the gas. Very few candidates attempted to test any gas even when the evolution of a gas had been recorded. As the gas was being evolved from warm hydrochloric acid the Examiners widened the tests on the gas which were to be allowed. These were testing with blue litmus (HCl from the acid), limewater (possibly CO₂) or acidified dichromate (SO₂). The correct result had to be seen. These were HCl from any of the solutions, no carbon dioxide from any solution and sulfur dioxide from **FB 3** or **FB 4**.
- (b) The results of the tests with aqueous sodium hydroxide and aqueous ammonia were generally well presented. Most candidates reported the effect of adding the reagent to excess when a precipitate was observed on first addition of the reagent. Many candidates observed a white precipitate for **FB 3** with each of the reagents – a precipitate that was soluble in an excess of aqueous sodium hydroxide but insoluble in an excess of aqueous ammonia. This observation was incorrect but led to a “correct” identification of an unexpected pair of ions for **FB 3** – Pb²⁺ and Al³⁺. A number of candidates referred to colourless precipitates, which is an inappropriate description of a white precipitate such as that obtained with dilute Mg²⁺(aq) and NaOH(aq). It would be very difficult to see such a precipitate in the solution. Many candidates in drawing conclusions failed to link the formation of no precipitate with either reagent with more than one ion. Three ions could have been offered – Ba²⁺, Ca²⁺ or NH₄⁺. Many candidates gave one cation for each of the solutions – ignoring the rubric that stated that a single cation could be identified for two of the solutions and a pair of cations for the remaining solution.
- (c) Where a pair of cations was given for one of the solutions in (b), one mark was given for suggesting a reagent that would correctly distinguish between the named ions. No mark was available for the observations in this section. Where NH₄⁺ was the ion to be detected in a stated pair it was important to explain that sodium hydroxide was the reagent to be used and that the gas evolved had to be tested with red litmus paper (or a pH indicator).

- (d) Many candidates appeared to have forgotten the information given at the start of the question that each solution contained a sulfite or a sulfate. Each of the solutions should therefore have given a white precipitate on addition of aqueous barium chloride. Many coloured precipitates, e.g. yellow, were recorded for **FB 2** where the white precipitate formed in a coloured solution containing $\text{Fe}^{3+}(\text{aq})$ ions.

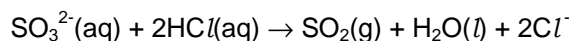
One mark was given for the solubility of the initial precipitate in hydrochloric acid for **FB 3** and **FB 4**. Many candidates reported that one or both of these precipitates were insoluble in the acid. Centres are reminded that the Confidential Instructions called for these solutions to be prepared from **freshly purchased** sodium sulfite to avoid the possibility of sulfate being present.

The second mark was for the white precipitate formed between **FB 2** and barium chloride. Because of the colour of the solution, the mark scheme was widened to allow an off-white or even a cream precipitate but not a yellow precipitate. This precipitate was insoluble on adding the acid – any change in its colour was ignored. Candidates should be encouraged to distinguish between a coloured precipitate and a white precipitate formed within a coloured solution.

The third mark in this section was for conclusions appropriate to the recorded observations. Chromate was allowed (error carried forward) for **FB 2** where a yellow precipitate had been recorded with the barium chloride.

A small number of candidates lost the conclusion mark by giving incorrect formulae for the ions present (stoichiometry or charge). Examiners currently make allowance for incorrect formulae when referring to reagents (providing the identity of the reagent is unambiguous) but correct formulae of ions or compounds are required in conclusions. The ion formulae are printed in the Qualitative Analysis Notes on the paper.

- (e) Very few candidates appeared to know what would happen if hydrochloric acid was added to a sulfite before the barium chloride was added. Some suggested that the acid converted the sulfite to sulfate. A few did comment that sulfur dioxide would be produced but not that the sulfite would be removed from solution.



The mark scheme was eased to allow a mark for those who said the precipitate had to be obtained first in order to test its solubility in the acid.

- (f) On adding potassium iodide to **FB 2** the Examiners were hoping to see a description of a colour change. Where no change, simply the final colour of the solution was recorded it had to be darker than the solution colour given for **FB 2** in (a) and in a range of colours suitable for aqueous iodine (yellow to brown, including red-brown but not red on its own). Many candidates did not give adequate information in this section.

Most candidates did observe the blue to black colour when starch was added. Both sections needed to be correct for the award of the first mark.

If either of the above were observed, the second mark was available for stating that a redox reaction had taken place or for specifically stating that iodide ions had been oxidised.

Many candidates spoiled this answer with statements such as “Potassium iodide oxidises iodide ions”, “iodide is an oxidising agent” or making one correct and one incorrect – contradictory – statement. Reference to displacement or oxidation on its own did not gain this second mark.



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<p>Paper 9701/33 Advanced Practical Skills 1</p>
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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 without seating plans or candidate lists and there is insufficient data to place candidates within each session and candidates may again 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.

Comments on specific questions

Question 1

This question was generally well answered by the majority of candidates. The weaker candidates usually gained at least 10/24 marks, and the better candidates gained marks in the 20-22 range. This may be partly due to no calculation involving moles arising from the titration results. However, unlike previous years, almost no candidates gained 24/24 marks as very few realised the significance of the information given in **1(g)**.

- (a)** Candidates should be reminded of the need for unambiguous headings. Although this was not a marking point, a number of candidates did not record masses to the same number of decimal places, nor were units included by some. Almost all candidates used the mass stipulated in the question.
- (b)** Most candidates gained this mark, although a few transposed the masses.
- (c)** Most candidates used values from **(b)** correctly, though a few did not calculate the M_r of water and/or iron (II) sulfate correctly. The most common errors were to round the values incorrectly or to give the number to moles to one significant figure only which is inappropriate at this stage of the calculation.
- (d)** Some candidates used involved methods of calculating the value for x rather than using the values found in **(c)** and a few slipped up in the mathematics. However, the majority used the correct ratio so gained the first mark without any problem. As it is extremely unlikely that the board would set a question of this type involving an efflorescent chemical, candidates should be instructed to expect the value for x to be an integer.

- (e) (i) Over 99% of candidates gained this mark.
- (ii) A large majority of candidates gained this mark. However, there are still candidates at a few Centres who did not include both burette readings **and** the titre. Fewer candidates than in previous examinations inverted burette readings, had an initial burette reading of 50.00 or more than one final volume of 50.00 cm³.
- (iii) Candidates should be reminded of the syllabus requirement for headings in a titration. A large minority lost this mark by writing initial/final 'volume' instead of initial/final burette reading. The units were presented correctly by the majority of candidates which is an improvement from previous examinations.
- (iv) The majority of candidates gained this mark but there were still individual candidates or even all candidates within a Centre where burette readings were not recorded to 0.05 cm³. Some Supervisors also gave readings to only one decimal place. There were also a few candidates who tried to interpolate readings to 0.01 or 0.02 cm³ and so lost this mark.
- (v) A large majority of candidates obtained concordant titres and would appear to be well practised in this skill.
- (vi) The Examiners selected the best titre value from the Supervisor results and used this as a standard for the relevant session/laboratory. A 'best' titre was similarly selected for each candidate and compared with that of the Supervisor. Points (vi) to (ix) were awarded for a difference up to 0.20 cm³, (vi) to (viii) for a difference of 0.20+ to 0.30 cm³, (vi) and (vii) for a difference of 0.30+ to 0.50 cm³, and (vi) only for a difference up to 0.80 cm³. Few candidates incurred a spread penalty of -1 applied if the corrected titres selected by the Examiner differed by 0.25 to 0.50, and -2 if the titres differed by more than 0.50 cm³. Any candidate performing only one accurate titre also incurred a penalty of -2.
- (x) Candidates should be reminded that at least two titres should be ticked and used to find the mean. An encouragingly small number of candidates lost this mark through a spread of (uncorrected) titres being greater than 0.20 cm³.
- (xi) The majority of the candidates calculated the mean of the selected titres correctly. However, they should be reminded to record the mean to the same number of decimal places as the burette readings.
- (f) There were fewer than expected responses of 0.05 cm³ as many candidates gave the maximum error for two readings in the first part of the question. These candidates were given the benefit of the doubt in the second part if the answer in the first part was not doubled before dividing by the titre and multiplying by 100. The second mark was more commonly lost by the answer not being given to a minimum of two significant figures.
- (g) Few candidates gained this mark as a large majority ignored the values for x given in the rubric and wrote that there was insufficient heating. Some candidates suggested overheating or under heating, and the combination lost them the mark. However, some candidates suggested that spitting or decomposition might have occurred.
- (h) Many of the answers were along the lines of heating to constant mass which was incorrect for the error given in the question. There were a few candidates who gave a suitable modification to the method, and explained that something other than water must have been driven off.

Question 2

- (a) The majority of candidates gained this mark by naming the dilute acid in (a) or (b) and choosing either aqueous silver nitrate or aqueous lead (II) nitrate. Some did not register that a single reagent was required for each test, and many chose to use a combination of aluminium and aqueous sodium hydroxide which was unsuitable for identifying nitrite alone. Whilst incorrect formulae for reagents was not penalised a significant number of 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 the name or formula of the reagent should 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.

- (b) Not all candidates completed both tests for **all** the unknowns and so reduced the marks available. Candidates should be informed that negative results are often relevant to identifying 'unknowns'. Although not penalised some of the candidates used different reagents from those specified in (a) for the tests. There appeared to be little contamination of test tubes from the observations made.
- (i) Most candidates recorded a brown gas, or at least effervescence, only with **FA5**. A majority of candidates also reported no change or no reaction with **FA5** and the second reagent.
- (ii) Very few candidates reported seeing a blue or colourless solution on adding acid to **FA5**.
- (iii) Most candidates reported seeing a white precipitate with aqueous silver or lead (II) nitrate and **FA6** and no reaction with acid. However, there were still candidates reporting 'white solution'. 'White' implies the presence of a solid or an emulsion so 'white solution' is a contradiction in terms.
- (iv) Most candidates reported seeing a yellow precipitate with aqueous silver or lead (II) nitrate and **FA7** and no reaction with acid.
- (v) Those using acid generally gained this mark.
- (vi) The majority of candidates produced sufficient correct observations to identify the chloride and iodide.
- (vii) The majority of candidates who used relevant reagents were able to give appropriate evidence for the identification of the three ions required.
- (c) The majority of candidates gained this mark. The errors were similar to those specified in (a) though the same error was not penalised a second time. A few candidates lost the mark by suggesting that lead (II) chloride would be suitable or by suggesting that (aqueous) ammonia be added without specifying that it should be added to the silver halide precipitate.

Question 3

- (a) The maximum mark for this part of the question was three instead of the four printed. Most candidates gained two marks. The mark most commonly awarded was for the reporting of the three precipitates, white in test (i) and (ii), and yellow in (v) though a few reported precipitates soluble in excess which lost the mark. The change of colour to green or blue in (iv) was also frequently awarded. Fewer candidates gained the mark for the observation in (iii) as some omitted either the initial colour of the solution or did not specify that no precipitate was formed/it remained a solution. Candidates should be reminded that colour changes require initial as well as subsequent colours to gain marks.
- (b) The majority of candidates gained this mark. Only a few failed to indicate the correct oxidation state of the lead ion. A common mistake was to suggest the presence of barium ions which was contradicted by the candidates' correct observations in (a) (i), or magnesium ions which was contradicted by the results in (a) (i), (ii) and (v). A few of those gaining the first mark did not supply sufficient supporting evidence for the second. Candidates should be reminded of the minimum evidence needed to support the identification of a particular ion.
- (c) The maximum mark for this part of the question was two. However, very few candidates gained both marks. Insufficient notice was taken of the question and thus the effect on or of ethanol was not specified. Answers tended to be vague with 'oxidation', 'reduction' or 'redox' being popular responses. Many gave the orange to green colour change as the supporting evidence without identifying the underlying chemistry. The colour changes needed to be related to the correct changes in the oxidation state of the chromium. A surprising number of those who wrote that the ethanol had been oxidised then failed to gain the second mark by suggesting that the product of the oxidation was ethanoic acid even though there was insufficient heating for more than ethanal to be formed. The most common incorrect response was 'esterification' and the production of a sweet smell in (a) (iv) given as the supporting evidence. Candidates' attention should be drawn to the practical assessment syllabus regarding exercises requiring knowledge of simple organic reactions.

CHEMISTRY

Paper 9701/034
Advanced Practical Skills 2

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;
- 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 without seating plans or candidate lists and there is insufficient data to place candidates within each session and candidates may again be disadvantaged.

Comments on specific questions

Question 1

This question was generally well answered by the majority of candidates. The weaker candidates usually gained at least 12/24 marks, and the better candidates gained marks in the 20-22 range. This may be partly due to no calculation involving moles arising from the titration results. However, unlike previous years, almost no candidates gained 24/24 marks as very few were sufficiently precise with regard to balance errors required in **1(f)(i)**.

- (a)** Candidates should be reminded of the need for unambiguous headings. Although this was not a marking point, a number of candidates did not record masses to the same number of decimal places, nor were units included by some. Almost all candidates used the mass stipulated in the question.
- (b)** Most candidates gained this mark, although a few transposed the masses.
- (c)** Most candidates used values from **(b)** correctly, though a few did not calculate the M_r of water and/or copper (II) sulfate correctly. The most common errors were to round the values incorrectly or to give the number of moles to one significant figure only which is inappropriate at this stage of the calculation.
- (d)** Some candidates used involved methods of calculating the value for x rather than using the values found in **(c)** and a few slipped up in the mathematics. However, the majority used the correct ratio so gained the first mark without any problem. As it is extremely unlikely that the board would set a question of this type involving an efflorescent chemical, candidates should be instructed to expect the value for x to be an integer.

- (e) (i) Over 99% of candidates gained this mark.
- (ii) A large majority of candidates gained this mark. However, there are still candidates at a few Centres who did not include both burette readings **and** the titre. Fewer candidates than in previous examinations inverted burette readings, had an initial burette reading of 50.00 or more than one final volume of 50.00 cm³.
- (iii) Candidates should be reminded of the syllabus requirement for headings in a titration. A large minority lost this mark by writing initial/final 'volume' instead of initial/final burette reading. The units were presented correctly by the majority of candidates which is an improvement from previous examinations.
- (iv) The majority of candidates gained this mark but there were still individual candidates or even all candidates within a Centre where burette readings were not recorded to 0.05 cm³. Some Supervisors also gave readings to only one decimal place. There were also a few candidates who tried to interpolate readings to 0.01 or 0.02 cm³ and so lost this mark.
- (v) A large majority of candidates obtained concordant titres and would appear to be well practised in this skill.
- (vi) The Examiners selected the best titre value from the Supervisor results and used this as a standard for the relevant session/laboratory. A 'best' titre was similarly selected for each candidate and compared with that of the Supervisor. Points (vi) to (ix) were awarded for a difference up to 0.20 cm³, (vi) to (viii) for a difference of 0.20+ to 0.30 cm³, (vi) and (vii) for a difference of 0.30+ to 0.50 cm³, and (vi) only for a difference up to 0.80 cm³. Few candidates incurred a spread penalty of -1 applied if the corrected titres selected by the Examiner differed by 0.25 to 0.50, and -2 if the titres differed by more than 0.50 cm³. Any candidate performing only one accurate titre also incurred a penalty of -2.
- (x) Candidates should be reminded that at least two titres should be ticked and used to find the mean. An encouragingly small number of candidates lost this mark through a spread of (uncorrected) titres being greater than 0.20 cm³.
- (xi) The majority of the candidates calculated the mean of the selected titres correctly. However, they should be reminded to record the mean to the same number of decimal places as the burette readings.
- (f) (i) Candidates' attention should be drawn to the syllabus requirement on estimating errors such as the errors intrinsic in measuring devices as 'random error' was the response from a minority of candidates.
- (ii) The majority of the candidates gained this mark.
- (g) Some candidates did not take note of the requirement of the question to provide an error in the **practical procedure** but the majority answered this part well. The mark was frequently awarded from the answers given in (h).
- (h) Most candidates gained at least one of the two marks in this part. A minority lost the first mark by not stating heat to constant mass, or did not state that the lower than expected value for **x** was due to the mass loss being too low in the second part.

Question 2

The majority of candidates performed well in this question with most gaining 6/9 to 9/9. Candidates who appeared to have transposed solutions in (a) were able to gain identity and evidence marks. There were still candidates who reported 'white solutions'. 'White' implies the presence of a solid or an emulsion so 'white solution' is a contradiction in terms. There appeared to be little contamination of test tubes from the observations made.

- (a) (i) A large majority of the candidates gained this mark.
- (ii) A large majority of the candidates gained this mark.

- (iii) The most common error was to omit adding aqueous sodium hydroxide in excess to **FB 8**.
 - (iv) A large majority of the candidates gained this mark.
 - (v) A large majority of the candidates gained this mark.
 - (vi) A large majority of the candidates gained this mark.
 - (vii) A large majority of the candidates gained this mark as evidence was only needed for the identification of two ions. Candidates should be reminded of the minimum evidence needed to support the identification of a particular ion.
- (b) The majority of candidates gained at least one of the two marks in this part. Whilst incorrect formulae for reagents was not penalised a significant number of 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 the name or formula of the reagent should 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. The most common errors in this part were to omit the second reagent, to fail to name the acid or name it as sulphuric acid, or to use lead (II) nitrate.

Question 3

This question was poorly answered. Few candidates gained more than 2/7 available marks. Candidates should be reminded of the gas tests and test results, and the common chemical reactions in which these gases are evolved.

- (a) (i) Very few candidates reported the evolution of a gas which relit a glowing splint. A small number noted a 'pop' with a lighted splint though hydrogen should not have been considered given the procedure. The majority of candidates did not appear to have heated **FB9** sufficiently strongly contrary to the instructions given.
 - (ii) Few candidates correctly reported that there was no gas evolved on warming. A larger number, though still a small minority, reported a gas evolved turning damp red litmus paper blue. Bubbling in this part implied a lack of care when heating with aqueous sodium hydroxide especially as the instruction for gentle heating and not allowing the mixture to boil was given in bold. Candidates should be informed that negative results are often relevant to identifying 'unknowns'.
 - (iii) This mark was the most commonly awarded in **Question 3**. The most common error was to omit that it was the **gas** turning the red litmus paper blue. The fourth mark in this section was rarely awarded as both gases had to be identified.
- (b) Few gained this mark. Common errors included the inclusion of incorrect elements and the identification of nitrate and/or nitrite ions instead of their constituent elements.
- (c) Few gained this mark. The most common error was to state that the aluminium foil acted as a catalyst. Less common was that it acted as an anti-bumping agent or was an oxidising agent.
- (d) A small minority of candidates gained this mark. The most common errors made by candidates were not giving the expected results of adding acid to both nitrate and nitrite, and suggesting that chlorine would be evolved.

CHEMISTRY

Paper 9701/41
A2 Structured Questions

General Comments

This paper provided candidates of all abilities with the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry.

Comments on Individual Questions

Question 1

- (a) Many candidates were able to distinguish between carbon dioxide being a simple molecular structure and silicon dioxide being a giant covalent structure. However, significantly fewer candidates stated the physical property of gas and solid respectively.
- (b) Candidates were able to use their knowledge of ceramic materials to suggest that silicon dioxide was hard, has a high melting point and is an electrical insulator, and that these properties are due to strong covalent bonds. A common error was to only give one property of a ceramic, whereas the question asked for properties and so candidates needed to give at least two correct properties.
- (c) (i) Almost all candidates gave the correct answer.
- (ii) Very few candidates were able to construct this equation correctly. This was often because they had a product of hydrogen or sodium alone. Candidates should remember some general chemical principles about likely and unlikely products when attempting questions of this type.
- (d) (i) A very large proportion of candidates correctly wrote the equation resulting in both tin and lead ions in the +2 oxidation state.
- (ii) Many candidates correctly calculated the values using the relevant *Data Booklet* information.
- (iii) A significant number of candidates calculated the number of moles of Sn^{2+} to be 6.75×10^{-4} mol in the first titration and 1.02×10^{-3} mol in the second titration. A very common error was to omit the ratio of 5/2 from the equation given in the stem of the question in both of these calculations.
- (iv) Very few candidates were able to use the calculations from part (iii) to correctly calculate the ratio in the oxide **A**. This was because they failed to recognise that the number of moles of Sn^{4+} needed to be calculated by subtracting the number of moles of tin in the first titration sample from the number of moles in the second titration sample. This gave a ratio of 2:1 and so the formula of **A** is Sn_3O_4 .
- (e) (i) Most candidates were able to correctly calculate the volume of tin as $1 \times 10^{-5} \text{ m}^3$ or 10 cm^3 . Those who made mistakes generally did so when trying to convert m^3 to cm^3 .
- (ii) As the density was given to candidates in units of g cm^3 , a conversion of the volume calculated in (i) was required from m^3 to cm^3 , which caused significant problems for many candidates. However, the majority were able to use a value of mass for the tin, the correct one being 73 g, and calculate the number of moles.
- (iii) The number of moles in (ii) was used correctly by a reasonable number of candidates and multiplied by the Faraday constant and also by 2 to calculate the quantity of electricity.

Question 2

- (a) There were many details that candidates needed to include correctly, such as state symbols, charges and balancing. Some candidates gave a general equation to represent lattice energy, rather than the specific calcium chloride one required by the question.
- (b)(i) and (ii) Many candidates knew the factors involved in relative magnitude of lattice energy, namely size of ions and charge on the ions. However, many candidates did not apply this knowledge correctly to compare calcium fluoride with calcium chloride in terms of anion size, and even less often to the comparison of the charge of the sulfide ion to the chloride ion when discussing calcium sulfide compared to calcium chloride.
- (c) Many candidates were able to complete this calculation correctly, making use of the *Data Booklet*, and almost all were able to make an attempt at constructing a diagram on which to base the calculation. The most common errors occurred in allocation of sign and in having two chlorine atoms to ionise.
- (d)(i) Many candidates were able to correctly calculate the empirical formula. Those candidates who made errors in their calculation often used atomic number instead of atomic mass.
- (ii) Very few candidates were able to use the empirical formula to suggest the formula for malonic acid. The first line of the question in (d) told candidates that it was a di-carboxylic acid and (ii) asked for the structure of this acid. Very few candidates drew structures that contained two carboxylic acid groups. Many candidates attempted to draw a structure for the empirical formula of the salt in (i), rather than the acid.

Question 3

- (a) Many candidates were able to identify one or two of the stages of this explanation. Marks were lost by candidates who described 'atoms' or even 'orbitals' being excited rather than electrons. The best answers that Examiners saw were those that began with d-orbitals being split or existing at two different energy levels, and then suggested what happens when visible light shines on electrons in such orbitals. Candidates should be encouraged to write logically when attempting this type of question.
- (b)(i) Candidates could answer this either from first principles from the graph or from their knowledge of the chemistry of copper. The graph indicated clearly that the two complexes are different in colour and candidates were required as a minimum to make the distinction between blue and dark blue.
- (ii) Many candidates scored no credit at all in this part. Candidates were required to observe that the graph indicated a greater absorbance of light for the amino-complex, since the height of the peak is higher, and also that this greatest absorbance occurred at a lower wavelength of light, i.e. in the visible region.
- (iii) Examiners were pleased to see that a great many candidates were able to sketch a peak for the intermediate complex with both height and position of the peak in between the two already present.
- (c)(i) This question was well answered by the majority of candidates. A common error was omitting the power of four for the concentration of chloride ions. Correct units were a little less reliably given.
- (ii) A correct answer was seen by Examiners on about half of the candidates' scripts. Candidates should practice manipulation of mathematical relationships so that they are confident to make any term the subject.

Question 4

- (a) Examiners were pleased that a great many answers clearly demonstrated that the solubility was as a result of hydrogen bonds forming with water because of the presence of an OH group.
- (b) Many candidates gave answers that were imprecise in their language, stating, for example, that electrons were delocalised, but not specifying which electrons they meant. Other weaker answers said that H^+ was lost more easily, but did not refer to either the stability of the phenoxide ion, or the weakening of the OH bond.
- (c) Examiners saw many candidates who were able to apply their knowledge to this situation very well indeed. The most common error was made by those candidates who judged that alkaline aqueous iodine would react with either or both of the compounds.
- (d) This question was very well answered by many candidates. A choice of either aqueous bromine or excess acidified dichromate(VII) ions allowed candidates distinguishing observations. A common error was choosing a reagent not listed in part (c). Candidates are reminded of the need to read each part of a question carefully.

Question 5

Only the strongest candidates performed well on the whole of this question. Weaker ones did not score very well, even on questions that required less application of knowledge than others. Many candidates were awarded most or all of the available marks in part (b).

- (a) (i) Reaction I and reaction II are standard reactions from the syllabus and as such were answered very well by many candidates, the most common correct responses being heating with acidified $KMnO_4$ for reaction I and PCl_5 for reaction II. Marks were lost by those candidates who omitted details such as heat or acid in their answers for reaction I.
- (ii) A structural formula is one that has bonds such as $C=O$ indicated and this was often omitted, even by some good candidates. A second main source of error was in the way that candidates indicated that their structure was one repeat unit of a polymer.
- (b) (i) Many candidates found this question difficult for various reasons, although Examiners felt that candidates who took the most care in general with their answers were more likely to score on this question than those who appeared to be in a rush to finish as quickly as possible, or those who wanted to complete their answers by writing as little as possible. The di-acid chloride C, reacts at both ends of the molecule. The CH_3NH_2 forms a peptide bond with each acid chloride group. Again the question asked for a structural formula, so those candidates who did not show $C=O$ were penalised here.
- (ii) A di-ester is the product of reacting the di-acid chloride with $HOCH_2CH_2OH$ (or a repeat unit of a polymer analogous to Kevlar).
- (c) (i) A significant number of candidates were unable to correctly work out that HCl will react with the NH_2 group (only) in compound D and that it reacts in the same way at each end.
- (ii) The reaction of D with bromine produced more correct responses from candidates and many gave molecules with two or more bromine atoms substituted on the ring.
- (d) **Reaction III**
This question tested recall of knowledge about reaction reagents and conditions, but Examiners were surprised to see so many candidates unable to give correct responses of nitrous acid at less than $10^\circ C$. Many candidates stated that HNO_3 was required rather than HNO_2 .

Reaction IV

Very few candidates gave correct responses to this question and even the condition of having NaOH present was omitted by many very good candidates.

- (e) (i) and (ii)** These questions were well answered by many candidates, who stated that a zwitterion is a species having positive and negative ionic centres/charges and were able to draw the structure of the zwitterions of 4-aminobenzoic acid. A significant number of candidates were not credited either because they drew zwitterions for a different molecule, or because they did not show the acid/amino group attached correctly to the ring. For example $\text{COO}_2^- \text{C}_6\text{H}_4 \text{NH}_3^+$ i.e. showing that the acid group is attached to the ring at the second oxygen (rather than at the carbon atom).

Question 6

- (a)** This question was very well answered, with the majority of candidates being able to draw the complementary DNA strand, labelling hydrogen bonds and naming the bases correctly from the pairing with the original strand.
- (b) (i) and (ii)** This part was not particularly well answered. Many candidates answered in a biological rather than a chemical way. For example, most candidates knew that the ribosome is where 'protein synthesis' (as asked about in the question) happens, but not so many were able to write about this in terms of forming the protein or polypeptide chain. Candidates who study biology as well as chemistry should make every effort to apply chemical knowledge about things such as the bonding involved when answering biochemistry questions.
- (c) (i)** Once again Examiners saw many answers that were not chemical in nature, and so did not refer to the change of a single base in the DNA chain. Many candidates made the mistake of describing the effect of a mutation, rather than the cause of this effect.
- (ii)** Quite a large number of candidates were able to describe some of the effects on bonding of a mutation. Again, candidates needed to answer in terms of the bonding involved, the reasons for these changes and so on, rather than a description of an example of such a mutation such as sickle cell anaemia.

Question 7

- (a) (i) and (ii)** Many candidates thought that this question was asking about the use of X-rays in hospitals to diagnose, for example, fractured bones, rather than as the question asked, X-ray crystallography. Of those candidates who read the question correctly, some were able to identify the technique as being useful for showing the arrangement of atoms in a molecule, and also were able to suggest that hydrogen, having only one electron, was insufficient to diffract the X-rays.
- (b)** Many candidates were able to suggest that the active site was the key feature of an enzyme that would lead to an understanding of the enzyme's biochemical behaviour.
- (c) (i)** Examiners were surprised by how few candidates were able to answer this question correctly in terms of protons spinning in a magnetic field.
- (ii)** Most candidates were able to make an attempt at interpreting this NMR spectrum. There were a number of ways in which candidates made mistakes, for example they did not explain how they had arrived at conclusions as expressly stated in the question or they were unable to use the data booklet information along with the relative peak height together and so suggested, for example, environments such as CH_3 or CH_2 for a peak height of 1. Candidates should make sure that in this type of question they are precise with their language. The environment to which they are referring must also be clear.

Question 8

- (a)** Many candidates gave a wrong answer here of buckminsterfullerene or buckyballs. They saw the words nanotubes and carbon and assumed it must be the same as previous questions on this topic. Candidates who read the information in the stem of the question seemed to be much more likely to correctly give graphite as a form of carbon.
- (b)** Even candidates who had given C_{60} as their answer in **(a)** were able to interpret the information to suggest that this was the required property. However, this conclusion did not very often cause them to alter their answer for **(a)** to a structure that does have layers, i.e. graphite. The most common incorrect answer was the ability of graphite to conduct electricity due to delocalised electrons.

- (c) Very few candidates were able to identify the nano scale at which this battery is made as the primary reason for a brittle solid being able to be rolled into a cylinder. Many candidates gave answers about buckyballs being curved, as questions in previous papers have involved.
- (d) Very few candidates were able to suggest something that was appropriate here. Quite a lot of wrong answers were because candidates included the state symbol (aq).

Question 9

- (a) Examiners were pleased to see a number of candidates make very good attempts at applying chemical knowledge to this unknown context.
- (i) Many candidates were able to identify the bonding type as covalent or coordinate or dative.
- (ii) The idea of cis-platin preventing DNA chains from unwinding was present in a pleasing number of answers. Examiners saw an enormous range of attempts at explanations for the prevention of replication. Candidates should remember to use their knowledge when answering this type of question.

CHEMISTRY

<p>Paper 9701/42 A2 Structured Questions</p>
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General comments

Most candidates attempted all the questions on this paper, and there was little evidence of them running out of time. Some of their answers were somewhat patchy, however, and once again it was noticeable that Organic Chemistry is not learned effectively by candidates in some Centres.

As in previous examinations, quite a number of candidates lost several marks through not reading the questions carefully enough. Thus in **Question 4(c)** some candidates ignored the number of C-F bonds in the compound, in **Question 5(b)** and **(c)** some candidates replaced chlorine with bromine, in **Question 8(c)** candidates often ignored the data provided and in **Question 9(b)** candidates often describe golf balls rather than golf clubs. No candidate threw away all of these marks, but several lost a good proportion of them through a lack of care and attention rather than a poor understanding of chemistry.

Although the overall standard was much the same as last year, there seemed to be a greater proportion of poor scripts, scoring only 20 – 25%.

The following comments should be read in conjunction with the published mark scheme for this paper.

Comments on specific questions

Question 1

- (a) Most candidates knew that the sulfates become less soluble down the group, but several lost marks for their explanation by not describing the reasons accurately enough. As far as size is concerned, it is the increase in the radius/size of the **cations**, rather than the atoms, that is important. This leads to a reduction in both lattice energy and in hydration energy, but it is the hydration energy that is the more significant term.
- (b)(i) Although many candidates could tackle this calculation, a significant number rounded the pressure term to 1.00×10^5 .
- (ii) Candidates who answered part (i) correctly were generally successful in this part.
- (iii) A significant number of candidates lost marks in this part by failing to calculate the M_r of barium sulfate correctly.
- (c)(i) Even those candidates who had calculated part (b) correctly did not necessarily use a Born-Haber cycle to correctly calculate the lattice energy here.
- (ii) It was rare to see a correct comparison of lattice energies argued successfully in terms of the relative sizes of the anions.

Question 2

- (a) Although many candidates did know the order of basicity of these compounds, not all were able to explain the order in terms of the donation of electrons from the alkyl group in ethylamine or the delocalisation of the nitrogen lone pair over the ring in phenylamine.
- (b) From the answers seen, it was apparent that large numbers of candidates had not carried out, or even seen this series of reactions in the laboratory. Answers were generally poor and only a small percentage of candidates scored more than minimal credit.

- (c)(i) Although many candidates were able to calculate the concentration of silver ions, a significant number struggled to correctly find the square root of K_{sp} .
- (ii) This part was more successfully answered with candidates using clear logic.
- (d)(i) Although many candidates gave the correct expression for K_c , a number were then unable to determine the units. Even if K_c had been incorrectly determined, it was still possible to gain credit for units if correct logic was used.
- (ii) This was not a high-scoring part of the question with a large proportion of candidates omitting at least one term from the expression for the concentration of NH_3 .
- (iii) Very few candidates were credited in this part. The Examiners were looking for logic based on the electron donation of the ethyl group making the lone pair on the nitrogen atom more available.

Question 3

- (a) Candidates were generally able to give two relevant properties.
- (b) As in **Question 2(b)**, it seemed that a large number of candidates had little or no experience of carrying out titrations using potassium manganate(VII). The important steps in the titration were often omitted and some could not even write a balanced equation for the reaction. Given that this is a familiar titration reaction, the marks were very disappointing.
- (c)(i) Although a pleasing number of candidates were able to work out the oxidation numbers of the species in the equation, only a small proportion were then able to completely balance the equation.
- (ii) If anything, this equation proved to be more challenging than that in **(c)(i)**.
- (d) Although most candidates recognised that this was a catalysed reaction, few mentioned that the Fe^{3+} was a homogeneous catalyst, or explained the two steps.

Question 4

- (a) A worrying number of candidates did not know the full definition of bond energy.
- (b) Once again it seemed that many candidates had not seen these reactions.
- (c) Although many candidates correctly calculated the C-F bond energy, a number considered three bonds rather than six, and others gave an incorrect sign for the bond energy, (although this was dependent on their definition in **(a)**).

Question 5

- (a) Few candidates managed to correctly tick all the appropriate boxes (only compound **B** did not have all coplanar carbon atoms).
- (b) The Examiners were looking for chlorine with a 'halogen carrier' (specified) in reaction **I** and chlorine in the presence of light or heat in reaction **II**. Less than half the candidates scored full marks.
- (c)(i) **H** was correctly identified by most candidates.
- (ii) Both here and in **(c)(iii)** candidates again seemed to lack practical understanding of the reagents and conditions.
- (iii) Reaction **III** was an oxidation reaction, whilst reaction **V** could be described as hydrolysis or nucleophilic substitution.

Question 6

- (a) This question was one of the highest scoring, with a significant number of candidates able to follow the syntheses. The compounds which caused the most problems were **J** and **K**, followed by **Q** where a carbon atom was often missed.
- (b) By contrast, the reaction conditions were frequently not known or guessed at, with candidates not even using basic organic chemistry to help them.
- (c) Identifying the type of reaction generally scored better, but as in **Question 5(c)(iii)** there seemed to be a general lack of understanding of organic chemistry.
- (d)(i) This was an amide.
- (ii) An amine was looked for here.

Question 7

Of the three applications questions this was the highest scoring, possibly due to its higher recall demand or the overlap with some of the A Level Biology syllabus, although all of the material was clearly from the Chemistry syllabus.

- (a) Most candidates were able to identify a peptide bond in primary structure, (although not all could draw it, and few described this as a covalent bond. Most candidates correctly gave hydrogen bonding in secondary structure, but not all could correctly draw an example of such a bond. In tertiary structure most candidates could name two examples, but again diagrams were often very poor or wrong.
- (b) This question showed up a weakness in candidates' knowledge of enzyme reactions, with only a tiny percentage scoring full marks, and around half failing to score any. Too often the answers given were vague with little or no information given about how enzymes work.
- (c) As in the above, few candidates gained full marks and less than half scored any credit. Candidates failed to recognise that the graph was typical of non-competitive inhibition, with the rate never reaching V_{\max} .

Question 8

- (a) Candidates lost marks here for an imprecise definition of partition coefficient, even though from their answers in part (b) they clearly knew how to use it.
- (b) Good candidates scored both marks here, even if they had lost a mark in part (a). The most common mistake was forgetting to deduct the concentration of pesticide in the hexane layer in the calculation.
- (c)(i) Most candidates knew that the ratio would be 3 : 1 rather than 1 : 1 for bromine, although some wrote this incorrectly as 1 : 3.
- (ii) Generally good candidates scored both marks here, but some seemed to lack the logic that each of the chlorines had a 3 : 1 chance of being ^{35}Cl , and hence failed to end up with a 9 : 6 : 1 ratio.
- (d)(i) The key to success in this question was to use the data provided, yet all too often candidates failed to do so and lost marks. In this part the Examiners were looking for dioxins and furans (without specifying particular examples).
- (ii) The answer expected here was PCBs from the data in the bar chart.
- (iii) A variety of sensible answers was allowed here, but it had to relate chemically to the process.
- (iv) Few candidates managed to deduce the correct answer.

Question 9

- (a) It was very surprising that so few candidates were credited. All that was required was to put the size of the materials in the correct sequence, and it was expected that all candidates would know that the nanosphere would be the smallest.
- (b) Poor reading of the question caused candidates to lose marks here, with a significant proportion describing golf balls rather than the shafts of golf clubs. Candidates were expected to deduce improvements in properties since they could not 'know' them.
- (c) Again, poor reading of the question prevented candidates gaining easy marks in this question. Examiners expected candidates to compare the wavelength of infrared radiation (heat) with light, and say that because it was longer it would be reflected by the nano-sized particles, whereas the light with its smaller wavelength would pass through the gaps.
- (d)(i) Answers expected here were in terms of resistance to corrosion or reaction. A simple description of 'shiny' was not sufficient.
- (ii) The answer expected here was in terms of the bactericidal properties that silver must possess, although few candidates deduced this.
- (iii) It was expected that candidates would be able to deduce that the small particle size would mean a very large surface area and a higher rate of dissolution.

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Paper 9701/51

Planning, Analysis and Evaluation

General comments

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

Comments on specific questions

Question 1

- (a) The first mark for indicating a direct proportionality was accessed by many candidates but the second point proved to be more challenging. The essence of the correct answer was to refer to increasing the concentration in terms of an increased number of particles thus leading further to increased collisions.
- (b) The potassium persulfate was generally seen as the independent variable with the rate identified as the dependent variable.
- (c) Only a very few candidates were able to identify the need for the iodine concentration to remain constant.
- (d) Common answers tended to only access the first three marks, often via the table in (f). These were awarded for choosing further experiments of lower persulfate concentration and indicating the need to maintain constancy of the other species and the total volume. It was not always clear as to how the various volumes were to be measured. A particular problem was arriving at the correct sequence for mixing the solutions with the reaction beginning with the final mixing of the persulfate and the iodide and subsequently correctly identifying the completion of the reaction.
- (e) The most common erroneous answer here was to comment on the accuracy of the burette rather than the need to have an accurate volume of sodium thiosulfate since this volume controlled the extent of the reaction.
- (f) To access both marks the table needed to contain either the volume or the concentration of the persulfate, the elapsed time for a reaction and an appropriate rate. For these and any other inclusions in the table, correct units were required. While many scored both marks, one mark was more the norm.
- (g) The general tenor of the responses here were in agreement with the initial statement in (a).

Question 2

- (a) The two columns required were the mass of iodine and the mass of zinc used, correctly designated and calculated. A common error was to calculate the total mass of zinc and this of course made difficulties in subsequent sections.
- (b) Most candidates were able to successfully calculate the moles of iodine and the moles of zinc, although some candidates used 254 for the relative molecular mass of iodine rather than 127. The confirmation of the formula of zinc iodide ZnI_2 necessitated the calculation of an appropriate molar

ratio. Unfortunately, some candidates only calculated the ratio to one significant figure and were thus unable to identify the two anomalous ratios, Students 3 and 8 in **section (c)**.

- (d) Rather than taking an average or plotting a graph many candidates only recalculated a molar ratio.
- (e) Of those candidates who were able to correctly identify the anomalous results many lost credit in failing to correctly associate an explanation to the appropriate error.
- (f) The confirmation of the formula of zinc iodide was very dependent on prior work. However many candidates were able to access this mark.
- (g) The erroneous focus of some of the candidates was on the likely percentage error of a balance rather than on the problems associated with the determination of small masses.
- (h) While many candidates correctly suggested the use of sodium thiosulfate almost as common was the suggested use of starch.

CHEMISTRY

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Comments on specific questions

Section A

Question 1

- (a) The correct answer to the first part of this question was based on the information detailed in the stem, which directed the candidates to conclude that the enthalpies of neutralisation were the same for strong acids. To access the second mark candidates needed to indicate that the enthalpy change was less exothermic due to the loss of energy occasioned by the need to ionise the weak acids.
- (b) Most candidates were able to identify the nature of the acid as the independent variable, following this with either an enthalpy change or a temperature change for the dependent variable.
- (c) The two points being looked for here were an indication either by word or diagram that an insulated container was to be used and the need for a constant volume throughout. The majority of the candidates were able to access both marks.
- (d) A large proportion of the candidates found this section difficult. The first mark was for a clear statement of both volume and concentration such that less than 6×10^{-2} mol of the acid was to be used, while the second mark was awarded for the concentration of the diprotic acids being half the concentration of the monoprotic acids. A further requirement was for a constant volume throughout.
- (e) The first mark in this section was for calculating the mass of the ethanedioic acid needed to prepare the solution corresponding to the response in (d). The three remaining marks were for the detail of how to prepare the standard solution. The first mark proved to be difficult to achieve while two marks were common out of the remaining three, the detail required being often incomplete.
- (f) The numerator of the correct expression consisting of product of the total mass of the solutions, 4.3, and the temperature change was generally accessed but the number of moles of hydrochloric acid, the denominator, was not.
- (g) Almost universally, correct; gloves and/or goggles being the most common correct response.

Question 2

- (a) The calculations were generally correct although some candidates were a little careless with the number of significant figures in their answers. Since the square of 2 is 4 with no other significant figures this was accepted as correct.

- (b) Of the three marks allocated to the graph work, the first was for the generally correct plotting and drawing of the first two graphs, the other two being for correctly plotting the final graph and then drawing a straight line through the points and the origin. Three marks were quite common here.
- (c) The correct response that the effusion time is directly proportional to the square root of the relative molecular mass was a frequent response for two marks, while a more general statement of proportionality achieved one mark
- (d) Very few candidates were able to confirm that the presence of water vapour would affect the diffusion rate most focusing on water impeding the movement of the syringe.
- (e) As in (d) problems of syringe movement were common and very few candidates were able to suggest that again the water vapour would be a problem since the relative molecular mass of water is significantly larger than that of hydrogen.

Question 3

Throughout **Question 3** calculations were treated consequentially, wherever possible as commencing from a previous answer. Although, because of the problems with (a) many candidates scored 3 marks for the question a number of fully correct answers were seen.

- (a) While many candidates were able to correctly calculate both the mass of copper and the mass of oxygen the third section where the mass of copper combined with 1.00 g of oxygen was asked for was often incorrect. The question seemed to have been misunderstood as not being a ratio, the most common answers being the masses of copper with one gram added e.g. mass of copper for Student 1 1.56 g giving an answer to (iii) of 2.56. This misunderstanding also marred some of the answers to **sections (c) and (d)**.
- (b) When calculated correctly the results clearly show that Students 1 and 4 had anomalous results and this section required a correct reason for either anomaly. For those candidates with erroneous results in (a) this section usually produced a zero mark.
- (c) The first mark here was for correctly calculating any average of the copper oxygen ratio the second mark being awarded if the anomalies had been excluded from the calculation.
- (d) In many of the calculations the one gram added in (a) was subtracted here prior to the final calculation.

