

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to the candidates with some pleasing performances.

Ten questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 8, 9, 11, 13, 20, 22, 28, 29, 33** and **35**. **Questions 38** and **39** were also answered correctly by a high proportion of candidates, suggesting they had sufficient time.

Seven questions can be said to have been found to be particularly difficult. Fewer than 25% of candidates chose the correct responses to each of **Questions 4, 6, 10, 24, 25, 37** and **40**.

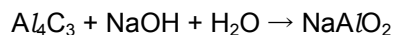
Comments on Specific Questions

Question 4

10% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 47% of candidates. If the original pressure is multiplied by 5/4 the answer obtained is **C**. However, this approach does not include converting the temperatures from Celsius to Kelvin. If the original pressure is multiplied by 373/(4x293) the answer obtained is **A**.

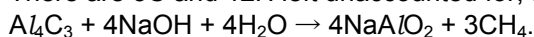
Question 6

13% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 77% of candidates. The information in the question allows the following equation to be constructed.



Balancing for Al, then Na, then O gives $\text{Al}_4\text{C}_3 + 4\text{NaOH} + 4\text{H}_2\text{O} \rightarrow 4\text{NaAlO}_2$.

There are 3C and 12H left unaccounted for; the only pure hydrocarbon that can form from these is methane.



Question 10

23% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 53% of candidates. This question was a matter of factual recall.

Question 24

23% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 50% of candidates. Acidified potassium dichromate(VI) will oxidise the OH in the secondary alcohol group, but not the OH in the carboxylic acid group. Sodium will react with both OH groups to give hydrogen gas, so the answer is **C**.

Question 25

20% of candidates chose the correct answer, **D**. Two incorrect answers were chosen more often; **B**, chosen by 37% of candidates and **C**, chosen by 30% of candidates. The attacking group here is OH^- , the leaving group is Br^- , these are both negative ions therefore they are both nucleophiles.

Question 37

20% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 40% of candidates. For many candidates, the question therefore depended on the truth or otherwise of statement 3. Statement 3 is incorrect as it describes CN^- as an electrophile rather than a nucleophile.

Question 40

13% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 43% of candidates. The key to this question is the small "dip between the two hills" in the reaction pathway diagram. This shows that the reaction must proceed in two separate stages. When considering the nucleophilic substitution reactions of halogenoalkanes this equates to the $\text{S}_{\text{N}}1$ mechanism, and therefore the substitution reactions of a tertiary halogenoalkane such as $(\text{CH}_3)_3\text{CBr}$.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to the candidates with some pleasing performances.

Ten questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 8, 9, 11, 13, 20, 22, 28, 29, 33** and **35**. **Questions 38** and **39** were also answered correctly by a high proportion of candidates, suggesting they had sufficient time.

Seven questions can be said to have been found to be particularly difficult. Fewer than 25% of candidates chose the correct responses to each of **Questions 4, 6, 10, 24, 25, 37** and **40**.

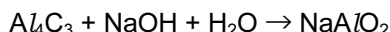
Comments on Specific Questions

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10% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 47% of candidates. If the original pressure is multiplied by 5/4 the answer obtained is **C**. However, this approach does not include converting the temperatures from Celsius to Kelvin. If the original pressure is multiplied by 373/(4x293) the answer obtained is **A**.

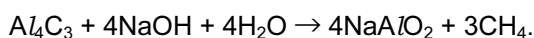
Question 6

13% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 77% of candidates. The information in the question allows the following equation to be constructed.



Balancing for Al , then Na , then O gives $Al_4C_3 + 4NaOH + 4H_2O \rightarrow 4NaAlO_2$.

There are 3C and 12H left unaccounted for; the only pure hydrocarbon that can form from these is methane.



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23% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 53% of candidates. This question was a matter of factual recall.

Question 24

23% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 50% of candidates. Acidified potassium dichromate(VI) will oxidise the OH in the secondary alcohol group, but not the OH in the carboxylic acid group. Sodium will react with both OH groups to give hydrogen gas, so the answer is **C**.

Question 25

20% of candidates chose the correct answer, **D**. Two incorrect answers were chosen more often; **B**, chosen by 37% of candidates and **C**, chosen by 30% of candidates. The attacking group here is OH^- , the leaving group is Br^- , these are both negative ions therefore they are both nucleophiles.

Question 37

20% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 40% of candidates. For many candidates, the question therefore depended on the truth or otherwise of statement 3. Statement 3 is incorrect as it describes CN^- as an electrophile rather than a nucleophile.

Question 40

13% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 43% of candidates. The key to this question is the small "dip between the two hills" in the reaction pathway diagram. This shows that the reaction must proceed in two separate stages. When considering the nucleophilic substitution reactions of halogenoalkanes this equates to the S_N1 mechanism, and therefore the substitution reactions of a tertiary halogenoalkane such as $(CH_3)_3CBr$.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General Comments

This examination paper proved to be accessible to the candidates with many pleasing performances.

Fourteen questions can be said to have been found to be easier. 70% or more of candidates chose the correct responses to each of **Questions 1, 2, 3, 5, 7, 9, 10, 11, 12, 13, 21, 28, 37 and 38**.

Seven questions can be said to have been found to be particularly difficult. Fewer than 45% of candidates chose the correct response to each of **Questions 17, 20, 27, 29, 30, 39 and 40**.

Comments on Specific Questions

Question 17

23% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 40% of candidates. Choice **C** was magnesium, but magnesium chloride solution produces a white precipitate with NaOH(aq) that is insoluble in excess alkali and therefore will not give a solution.. The correct

answer was aluminium, **A**. Aluminium chloride solution will give a white precipitate with NaOH(aq) that dissolves in excess alkali.

Question 20

32% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**, chosen by 31%. There are five isomers of C₅H₁₀O that are aldehydes: pentanal, the two optical isomers of 2-methylbutanal, 3-methylbutanal, and dimethylpropanal. Candidates choosing **B** may not have appreciated that 2-methylbutanal exists as a pair of optical isomers.

Question 27

40% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 45% of candidates. The reaction described is the substitution of CN for Br, followed by the hydrolysis of CN to COOH. The starting material must therefore have one carbon atom less than the final product given in the question.

Question 29

36% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 32% of candidates. These figures suggest that the majority of candidates knew that the cyclohexyl rings, for example, are non-planar. Those choosing **D** also believed that cholesterol displays cis-trans isomerism at the double bond. This is not possible where the double bond is constrained within a ring system.

Question 30

21% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 39% of candidates. Candidates should be reminded that in questions such as this, they are advised to draw skeletal or structural formulae in order to work out the correct answer.

Question 39

43% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 35% of candidates. The key to the question is the words “coloured **organic** product”. Ethanal undergoes a condensation reaction with 2,4-DNPH, giving an organic product which is an orange precipitate, so statement 1 is a correct answer. When ethanol is oxidised by acidified potassium dichromate(VI) a colour change *is* seen, but the organic products, ethanal and ethanoic acid, are colourless, so statement 2 is not a correct answer.

Question 40

31% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 57% of candidates. For the majority of candidates this question therefore depended on the truth, or otherwise, of statement 1. The HCN molecule is a weaker nucleophile, being polar but not being an ion. The CN⁻ ion is a stronger nucleophile, having a full negative charge.

CHEMISTRY

Paper 9701/21

AS Structured Questions

Key Messages

Candidates are reminded to read questions carefully and check answers thoroughly. In this paper, candidates would have benefitted from this particularly in **Questions 1(d)(ii), 1(d)(iv), 2(b)(ii), 4(a) and 4(c)**, where answers frequently included unbalanced equations or, in some cases, no equations at all.

Candidates need to ensure that **all** equations given are balanced and are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. This was especially important in **Question 2(d)(iii)**.

Candidates are advised to make sure that keywords and definitions are learnt thoroughly; not only so that questions such as **3(b)(i)** can be answered correctly, but also so that the correct basic principles of chemistry can be applied. This is especially true when explaining ideas such as trends in ionisation energies and melting points.

General Comments

This paper tested a range of recall and application skills from across the AS syllabus and discriminated effectively between all candidates. It did highlight, however, some syllabus areas with which candidates were less familiar; specifically Group II chemistry, shapes of molecules and equilibrium-based calculations.

Comments on Specific Questions

Question 1

- (a) (i) There were many good answers to this question although some candidates unnecessarily repeated the question in their responses. Any explanation of an ionisation trend down a group should always refer to the changing size of the **attraction** between the nucleus and electrons, in terms of the changing **distance** and **shielding**. Some candidates responded that the distance and shielding effects resulted in *less energy being needed* to remove the outermost electron. As the question states that the ionisation energies decrease down the group there could be no credit for this.
- (ii) Once again, as a comparison of ionisation energies is involved, a key part of the answer must be a reference to the attraction from the nucleus. The most common mistake here was to refer to 'orbitals' or 'sub-shells' when the large difference between 2nd and 3rd ionisation energies here needs explaining in terms of the fact that the 3rd electron is in a **shell** closer to the nucleus than the first two electrons.
- (b) (i) A surprising number of candidates suggested that the outer configuration was 4d² instead of 5s².
- (ii) Many candidates were able to state correctly that the four peaks are due to the presence of four isotopes although many referred to isomers instead of isotopes. Many were not specific and did not state *four*.
- (iii) Most candidates are comfortable with this standard calculation although some did not recognise the need to give the answer to three significant figures, despite it being asked for in the question.
- (c) (i) This was generally well answered although there was some inversion in the answers with candidates defining oxidation (loss of electrons) instead of defining an oxidising agent (an electron acceptor).

- (ii) This calculation was also generally well done although some candidates used the wrong atomic mass for Ba.
- (d)(i) A majority of candidates correctly identified **X**, **Y** and **Z** although there were quite a few who got MgO and Mg(OH)₂ the wrong way round and others who gave incorrect formulae.
- (ii) Most candidates suggested nitric acid as the reagent needed but here, as in several other equation-based questions, balancing caused problems for many candidates.
- (iii) Most correctly suggested heat here.
- (iv) Several candidates suggested reactions of Mg with something other than water despite the labelling on the reaction scheme.

Question 2

- (a) The equation was generally well done although balancing again caused some problems and some candidates thought that the formula of iron(III) oxide was FeO₃.
- (b)(i) Few candidates offered the key idea that the reaction is too exothermic though many earned credit with a reference to the production of an acid spray.
- (ii) This gave another example of the importance of reading the question carefully as the stem of (b) described this two-step process. However, many candidates did not provide two correct equations.
- (c)(i) Many candidates offered dot-and-cross diagrams, which are not required when the question is about the shape – but this may have been intended as an aid to working out if/how many lone pairs were present. A significant number of candidates incorrectly offered a linear shape for SO₂.
- (ii) Many candidates struggled with the recall of bond angles here.
- (d)(i) It was pleasing to see that so many candidates noted that there were four marks available for this answer as it led to a significant number of sufficiently detailed and well-explained responses. Some candidates confused the concepts of rate and equilibria and care must be taken to avoid suggesting that only the rate of the forward or reverse reaction increases when temperature is increased. Both rates increase when temperature is increased (i.e. the overall rate at which equilibrium is attained increases) but the position of equilibrium shifts in the endothermic direction whenever temperature is increased.
- (ii) The most common problem encountered here was for candidates to include square brackets in their expressions. The use of square brackets specifically refers to concentration (in mol dm⁻³) so they should only be used when an expression is being written for K_c , not K_p .
- (iii) This proved to be one of the more challenging questions on the paper. As advised in previous examiner reports, the key in questions of this type is to remember that there are potentially three quantitative pieces of information about each species in the equation: initial amounts, final/equilibrium amounts and the amounts reacting or being produced. Crucially, the stoichiometric ratio shown in the equation only applies to the last of these. In this case the **initial** amounts of SO₂ and O₂ were given as 2.00 mol each, and the **final/equilibrium** amount of SO₃ as 1.80 mol. From this it can be deduced that 1.80 mol of SO₃ has been produced during the reaction. As the ratio of SO₂:SO₃ is 1:1, the amount of SO₂ that has **reacted** must be the same meaning that 2.00 – 1.80 i.e. 0.20 mol will remain. The ratio of O₂:SO₃ is, however, 1:2 meaning that, to produce a given number of moles of SO₃, half that many moles of O₂ need to react. In this case 0.90 mol of O₂ will react in order to produce 1.80 mol of SO₃ meaning that 1.10 mol will remain in the equilibrium mixture. The next stage was to calculate mole fractions for each species followed by partial pressures before generating the final answer. Credit was available here for each stage of the calculation; candidates should be reminded that this is only possible for Examiners if all working is clearly shown.

Question 3

- (a) The reaction between an alkene and hot, concentrated potassium manganate(VII) seems to be well known by most candidates although some struggled to apply the concept in this context. Candidates would benefit from more practice at correct representations of structural formulae as many were confusing. Candidates should be encouraged to use brackets to show, for example, $\text{H}_2\text{C}=\text{C}(\text{CH}_3)_2$ or $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{CH}_3$ rather than the incorrect $\text{H}_2\text{C}=\text{CCH}_3\text{CH}_3$ although this was not penalised. Candidates are strongly advised to include the double bond when drawing the structural formula of an alkene as it helps to ensure the correct number of carbon bonds in the structure and also removes ambiguity.
- (b) (i) The definition of *stereoisomerism* (as “molecules with the same molecular and structural formula but a different spatial arrangement of their atoms”) was not well known by candidates. Descriptions of structural isomerism or stereoisomerism were often incorrectly given.
- (ii) Candidates must be aware that the formal definition of a **displayed** formula is one that shows **all** atoms and bonds in a molecule. The commonest mistake made here was to abbreviate the CH_3 groups instead of drawing them ‘displayed’. Candidates must also be aware that, when a question asks for the **name** of a compound, the full name is expected. In this case many candidates were not awarded credit as they labelled their structures as ‘cis’ and ‘trans’ without including ‘but-2-ene’.
- (c) Most candidates chose a suitable reducing agent but a significant minority offered a structure instead of the name of the product.

Question 4

- (a) Candidates very often wrote an equation that was correct apart from balancing of the species.
- (b) (i) The vast majority of candidates recognised that this reaction was an oxidation.
- (ii) Following on from (i) candidates were then able to suggest a suitable oxidising agent. Many candidates did not specify ‘reflux’, which is necessary to ensure complete oxidation to the carboxylic acid as opposed to the intermediate aldehyde.
- (c) This proved to be one of the most difficult questions on the paper. Relatively few candidates were able to apply the idea of an acid reacting with a carbonate, into this organic context. Very few recognised that the formula of the salt produced would be $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Ca}$ as the calcium ion has a 2+ charge.
- (d) (i) This was generally well answered although some candidates did not specify that the sulfuric acid should be concentrated.
- (ii) This was well answered.

CHEMISTRY

Paper 9701/22

AS Structured Questions

Key Messages

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Candidates need to ensure that **all** equations given are balanced and are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. This was especially important in **Question 2(d)(iii)**.

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General Comments

This paper tested a range of recall and application skills from across the AS syllabus and discriminated effectively between all candidates. It did highlight, however, some syllabus areas with which candidates were less familiar; specifically Group II chemistry, shapes of molecules and equilibrium-based calculations.

Comments on Specific Questions

Question 1

- (a) (i) There were many good answers to this question although some candidates unnecessarily repeated the question in their responses. Any explanation of an ionisation trend down a group should always refer to the changing size of the **attraction** between the nucleus and electrons, in terms of the changing **distance** and **shielding**. Some candidates responded that the distance and shielding effects resulted in *less energy being needed* to remove the outermost electron. As the question states that the ionisation energies decrease down the group there could be no credit for this.
- (ii) Once again, as a comparison of ionisation energies is involved, a key part of the answer must be a reference to the attraction from the nucleus. The most common mistake here was to refer to 'orbitals' or 'sub-shells' when the large difference between 2nd and 3rd ionisation energies here needs explaining in terms of the fact that the 3rd electron is in a **shell** closer to the nucleus than the first two electrons.
- (b) (i) A surprising number of candidates suggested that the outer configuration was 4d² instead of 5s².
- (ii) Many candidates were able to state correctly that the four peaks are due to the presence of four isotopes although many referred to isomers instead of isotopes. Many were not specific and did not state *four*.
- (iii) Most candidates are comfortable with this standard calculation although some did not recognise the need to give the answer to three significant figures, despite it being asked for in the question.
- (c) (i) This was generally well answered although there was some inversion in the answers with candidates defining oxidation (loss of electrons) instead of defining an oxidising agent (an electron acceptor).

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- (ii) Many candidates struggled with the recall of bond angles here.
- (d)(i) It was pleasing to see that so many candidates noted that there were four marks available for this answer as it led to a significant number of sufficiently detailed and well-explained responses. Some candidates confused the concepts of rate and equilibria and care must be taken to avoid suggesting that only the rate of the forward or reverse reaction increases when temperature is increased. Both rates increase when temperature is increased (i.e. the overall rate at which equilibrium is attained increases) but the position of equilibrium shifts in the endothermic direction whenever temperature is increased.
- (ii) The most common problem encountered here was for candidates to include square brackets in their expressions. The use of square brackets specifically refers to concentration (in mol dm⁻³) so they should only be used when an expression is being written for K_c, not K_p.
- (iii) This proved to be one of the more challenging questions on the paper. As advised in previous examiner reports, the key in questions of this type is to remember that there are potentially three quantitative pieces of information about each species in the equation: initial amounts, final/equilibrium amounts and the amounts reacting or being produced. Crucially, the stoichiometric ratio shown in the equation only applies to the last of these. In this case the **initial** amounts of SO₂ and O₂ were given as 2.00 mol each, and the **final/equilibrium** amount of SO₃ as 1.80 mol. From this it can be deduced that 1.80 mol of SO₃ has been produced during the reaction. As the ratio of SO₂:SO₃ is 1:1, the amount of SO₂ that has **reacted** must be the same meaning that 2.00 – 1.80 i.e. 0.20 mol will remain. The ratio of O₂:SO₃ is, however, 1:2 meaning that, to produce a given number of moles of SO₃, half that many moles of O₂ need to react. In this case 0.90 mol of O₂ will react in order to produce 1.80 mol of SO₃ meaning that 1.10 mol will remain in the equilibrium mixture. The next stage was to calculate mole fractions for each species followed by partial pressures before generating the final answer. Credit was available here for each stage of the calculation; candidates should be reminded that this is only possible for Examiners if all working is clearly shown.

Question 3

- (a) The reaction between an alkene and hot, concentrated potassium manganate(VII) seems to be well known by most candidates although some struggled to apply the concept in this context. Candidates would benefit from more practice at correct representations of structural formulae as many were confusing. Candidates should be encouraged to use brackets to show, for example, $\text{H}_2\text{C}=\text{C}(\text{CH}_3)_2$ or $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{CH}_3$ rather than the incorrect $\text{H}_2\text{C}=\text{CCH}_3\text{CH}_3$ although this was not penalised. Candidates are strongly advised to include the double bond when drawing the structural formula of an alkene as it helps to ensure the correct number of carbon bonds in the structure and also removes ambiguity.
- (b)(i) The definition of *stereoisomerism* (as “molecules with the same molecular and structural formula but a different spatial arrangement of their atoms”) was not well known by candidates. Descriptions of structural isomerism or stereoisomerism were often incorrectly given.
- (ii) Candidates must be aware that the formal definition of a **displayed** formula is one that shows **all** atoms and bonds in a molecule. The commonest mistake made here was to abbreviate the CH_3 groups instead of drawing them ‘displayed’. Candidates must also be aware that, when a question asks for the **name** of a compound, the full name is expected. In this case many candidates were not awarded credit as they labelled their structures as ‘cis’ and ‘trans’ without including ‘but-2-ene’.
- (c) Most candidates chose a suitable reducing agent but a significant minority offered a structure instead of the name of the product.

Question 4

- (a) Candidates very often wrote an equation that was correct apart from balancing of the species.
- (b)(i) The vast majority of candidates recognised that this reaction was an oxidation.
- (ii) Following on from (i) candidates were then able to suggest a suitable oxidising agent. Many candidates did not specify ‘reflux’, which is necessary to ensure complete oxidation to the carboxylic acid as opposed to the intermediate aldehyde.
- (c) This proved to be one of the most difficult questions on the paper. Relatively few candidates were able to apply the idea of an acid reacting with a carbonate, into this organic context. Very few recognised that the formula of the salt produced would be $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Ca}$ as the calcium ion has a 2+ charge.
- (d)(i) This was generally well answered although some candidates did not specify that the sulfuric acid should be concentrated.
- (ii) This was well answered.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key Messages

Candidates are reminded to read questions carefully and check answers thoroughly. In this paper, candidates would have benefitted from this in the answers to **1(b)**, **2(b)** and **2(d)(i)**, where they often presented too much information, or made unnecessary/careless repetition.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was similar to last year with good recall of material shown across the paper. Of note in this session was the clarity and good presentation of many scripts.

Comments on Specific Questions

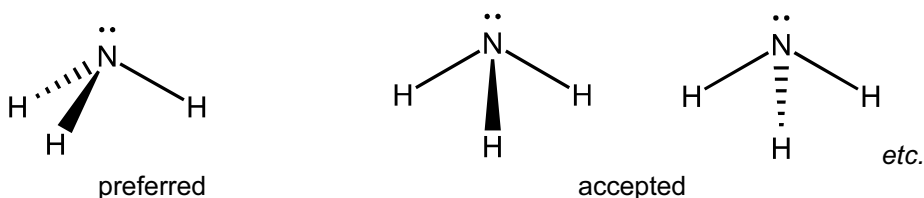
Question 1

- (a) (i) Few full-credit answers were seen; the three themes of distance from the nucleus/relative energy of the outer electrons, the increased screening (shielding) effect of extra inner shells, and the resulting attraction to the nucleus needed to be mentioned.
- (ii) The greatest misunderstanding in this question was to continue to discuss the difference in ionisation energies of the three halogens, rather than to focus on successive ΔH values of fluorine alone. Candidates are advised to practise writing responses to such questions, and to be precise with the language they use.
- (b) This part was well answered by many, though a common error was to state and argue for a trend that would be the opposite of that which exists. The use of 'bonds' where 'forces' should have been used was a common error.
- (c) (i) This question was well answered by most, with a number of different numerical methods used. The third marking point was awarded for demonstrated use of the M_r value of 222. Candidates therefore needed to show all working in order to achieve maximum credit.
- (ii) Many candidates were adept at showing the 'dot-and-cross' diagram, with most then correctly noting the difference in electronegativity between iodine and chlorine. The most common mistake was to have iodine as more electronegative than chlorine.
- (d) (i) Candidates showed good recall of group VII chemistry, though the identity of **W** was given as NaClO, rather than NaClO₃, by many.
- (ii) ECF was awarded to candidates who had identified **W** incorrectly as NaClO.
- (iii) Candidates were able generally to take the information given in the stem to say that chlorine had an oxidation number of -1 in NaCl. To gain credit though, it was necessary to state the original oxidation number (0) as well. Again, ECF was awarded for an answer of $+1$ if referring to NaClO.

- (iv) This question had a surprisingly high omission rate for a straightforward task. Many also missed the requirement for an **ionic** equation and/or for state symbols to be included.

Question 2

- (a) There were many correct answers to this part.
- (b) Some good, full answers were seen here, though many candidates' annotations to the diagram were contradictory to their written answers. There seems to be a common confusion between the Boltzmann distribution and an energy-profile diagram. Some candidates also attempted to answer the question of catalysis using a differently shaped distribution (for e.g. higher temperatures). Examiners would like to bring candidates' attention to the requirement of a statement about the frequency of successful collisions in such a question.
- (c) Although many candidates were able to draw a decent three-dimensional diagram for ammonia, the knowledge of shape and, moreover, bond angle needs improvement. Examiners would like to see candidates use both the 'solid' and 'dashed' wedges in their representations, although credit was given for a range of answers.



- (d) (i) Many candidates clearly understood Le Chatelier's Principle, but were not able to be explicit enough when stating **and** explaining their answers.
- (ii) There were many correct answers to this part. Common errors included expressions in terms of concentrations or the use of wrong indices.
- (iii) Examiners were pleased to be able to award full credit for many K_p calculations. The great majority of candidates attempted the calculation in the same fashion, variously forgetting the following steps:
- the calculation of equilibrium amounts
 - the calculation of equilibrium mole fractions
 - the calculation of equilibrium partial pressure **and/or** the use of indices when substituting the total pressure into an overall fraction.

Question 3

- (a) There were many correct answers to this part. However, simple errors in structural formulae were often seen, as were attempts to form two products from one alcohol – a case of misinterpretation of the role of the acidified potassium manganate(VII).
- (b) (i) Surprisingly, this question was answered the least well. The answer required a simple definition, with two key statements.
- (ii) This question was correctly answered by many candidates, though many also did not name the molecule, choosing merely to state which isomer was the *cis* or *trans* version.
- (c) There were many correct answers to this part.

Question 4

- (a) This question was well answered. An alternative answer to concentrated H_2SO_4 or H_3PO_4 was the use of Al_2O_3 , although many of these answers could only be awarded partial credit, as they did not

identify the specific conditions under which this may be used, and that propan-1-ol needed to be gaseous.

- (b) (i) This question was not well answered: many candidates were unable to incorporate [O] in a balanced chemical equation.
- (ii) Examiners were specifically looking for (heated) reflux conditions, to be sure that candidates understood how the reaction would be carried out in the laboratory
- (c) This question was very well answered by most.
- (d) This question had a high omission rate, though it was well answered by many. Some candidates neglected the alcoholic solvent, whilst others contradicted themselves by suggesting that the solvent was alcohol/ethanol but the reagent was NaOH(aq).

CHEMISTRY

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

- Thermometer readings should be recorded to the nearest 0.5 °C as this indicates the level of precision of the apparatus.
- The plotting of points on graphs and drawing lines of best fit requires the use of a sharp pencil and a long ruler. Points should be plotted precisely and all plotted data should occupy over half the grid in either direction. Straight lines of best fit should be drawn using a ruler and there should be an even distribution of points on either side of the line with any anomalies clearly labelled.
- Errors and improvements should be discussed when carrying out quantitative practical work during the course.
- Conclusions and inferences must be drawn from the actual results of tests carried out and are different from observations.
- Instructions in the rubric need to be read and acted upon.

General Comments

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- 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 to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and a wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

- (a) Almost all candidates recorded all the required balance readings and thermometer readings but a minority did not record all thermometer readings at .0 °C or .5 °C or recorded all readings at .0 °C. With a calibration at 1 °C, this is the accuracy to which readings should be taken. The majority of candidates gave suitable headings to their tables and displayed the units of temperature, time and mass correctly. Some recorded time in minutes but gave /s as the unit. Most candidates received at least partial credit for accuracy. A few Centres seemed to have supplied their candidates with incorrect masses of magnesium powder. It is important that the amounts specified in the Confidential Instructions are given to all candidates so that none is disadvantaged.
- (b) Almost all candidates labelled the axes correctly, though a number chose scales that did not occupy over half the available space. The plotting was generally good though some candidates were imprecise in the placing of points and some used large blobs that were not centred in the correct position to denote points. A few used such faint pencil marks that it was difficult for Examiners to read them. Those choosing to use difficult scales such as 7 °C to one large square tended to be inaccurate in their plotting. A significant number of candidates did not extrapolate the lines to 2.5 minutes, whilst some did not have balanced points on each side of the line after 2.5

minutes. Most candidates who extrapolated their lines gained credit for the theoretical temperature change.

- (c) A significant number of candidates gave a conclusion rather than an observation in (i): 'all the magnesium reacted' is a conclusion from an observation such as 'there was no solid left' or 'all the magnesium disappeared'. Candidates from many Centres were clearly well prepared for dealing with this type of calculation and gained credit in (ii) and (iii). Some used the mass of magnesium in (ii) instead of using the information given in the question with the value of c . Most candidates gave their final answer to an appropriate number of significant figures and gave the correct sign for ΔH .
- (d) The majority of candidates received full credit for this section but a few did not repeat the experiment with **FA 5** or gave headings that were ambiguous for their results. Candidates should be advised to read through a question and to prepare a table for all the results they are told to obtain before starting any practical work.
- (e) Almost all candidates who carried out the experiment with both **FA 4** and **FA 5** gained credit for (i) and (ii). Most candidates successfully calculated the numbers of moles of copper(II) sulfate and magnesium used in (iii). However, some stopped there and did not go on to show that the copper(II) sulfate was in excess. Good answers referred to the equation for the reaction and/or the mole ratio of the reactants.
- (f) 'Show clearly how you obtained your answer' was ignored by many. However, many candidates drew suitable Hess' cycle diagrams or showed the equation for **Reaction 2** reversed. A greater number of candidates successfully calculated the enthalpy change for **Reaction 3**.
- (g) Some excellent answers to both parts were seen, indicating that some Centres had spent time in discussing errors and improvements. Many candidates had the right idea in (i), stating that the graphical method was more accurate but they did not go on to connect this to dealing with heat loss. More candidates gained credit in (ii) for connecting greater volume with smaller ΔT but many stopped at stating that copper(II) sulfate was already in excess or there would be no difference in outcome.

Question 2

- (a) Some candidates only stated two nitrogen-containing ions in (i) with NH_4^+ being most frequently missed. Most candidates incorrectly suggested warming the unknown, **FA 6**, with aluminium and aqueous sodium hydroxide; this would give a positive result with all three possible ions and was not therefore suitable to distinguish between them. Candidates should always name any acid chosen as a reagent.

The observations recorded in (ii) were generally good though a minority claimed red litmus turned blue on warming the unknown with aqueous sodium hydroxide suggesting the litmus went into the solution rather than testing any gas evolved. Candidates need to ensure clarity of their work, for example, some seemed to add the acid to the tube containing **FA 6** plus aluminium and sodium hydroxide. Some candidates had sufficient observations when testing the ions suggested in (i) to come to a correct conclusion in (iii). However, some concluded nitrate without carrying out sufficient tests for this ion.

- (b) A large number of candidates recorded a correct observation in the first test and many gained full credit for the second test. The most frequent errors were recording a cream or green precipitate with **FA 7** plus aqueous potassium iodide or a brown precipitate or solution when testing with glucose. However, many obtained the expected silver mirror in the third test.
- (c) Many candidates gained at least half of the credit available here. The most frequently awarded marking point was in (i) for **FA 8** turning yellow on heating. Many candidates did not realise that the instruction 'leave to cool' indicated a further observation should be made. Many candidates reported effervescence/fizzing/bubbling in (ii) but far fewer went on to test the gas. Some reported 'a gas was evolved' which is a conclusion rather than an observation. It is possible that some candidates did not realise in (iii) and (iv) that a large excess of alkali would need to be added. **FA 8** was reacted with nitric acid to put the cation into solution so any acid remaining needed to be neutralised before the cation would form a precipitate and even more alkali needed to be added to

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have excess present. The majority of candidates correctly concluded CO_3^{2-} but fewer were able to identify the cation as Zn^{2+} .

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Thermometer readings should be recorded to the nearest 0.5 °C as this indicates the level of precision of the apparatus.
- The plotting of points on graphs and drawing lines of best fit requires the use of a sharp pencil and a long ruler. Points should be plotted precisely and all plotted data should occupy over half the grid in either direction. Straight lines of best fit should be drawn using a ruler and there should be an even distribution of points on either side of the line with any anomalies clearly labelled.
- Errors and improvements should be discussed when carrying out quantitative practical work during the course.
- Conclusions and inferences must be drawn from the actual results of tests carried out and are different from observations.
- Instructions in the rubric need to be read and acted upon.

General Comments

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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and a wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

- (a) Almost all candidates recorded all the required balance readings and thermometer readings but a minority did not record all thermometer readings at .0 °C or .5 °C or recorded all readings at .0 °C. With a calibration at 1 °C, this is the accuracy to which readings should be taken. The majority of candidates gave suitable headings to their tables and displayed the units of temperature, time and mass correctly. Some recorded time in minutes but gave /s as the unit. Most candidates received at least partial credit for accuracy. A few Centres seemed to have supplied their candidates with incorrect masses of magnesium powder. It is important that the amounts specified in the Confidential Instructions are given to all candidates so that none is disadvantaged.
- (b) Almost all candidates labelled the axes correctly, though a number chose scales that did not occupy over half the available space. The plotting was generally good though some candidates were imprecise in the placing of points and some used large blobs that were not centred in the correct position to denote points. A few used such faint pencil marks that it was difficult for Examiners to read them. Those choosing to use difficult scales such as 7 °C to one large square tended to be inaccurate in their plotting. A significant number of candidates did not extrapolate the lines to 2.5 minutes, whilst some did not have balanced points on each side of the line after 2.5

minutes. Most candidates who extrapolated their lines gained credit for the theoretical temperature change.

- (c) A significant number of candidates gave a conclusion rather than an observation in (i): 'all the magnesium reacted' is a conclusion from an observation such as 'there was no solid left' or 'all the magnesium disappeared'. Candidates from many Centres were clearly well prepared for dealing with this type of calculation and gained credit in (ii) and (iii). Some used the mass of magnesium in (ii) instead of using the information given in the question with the value of c . Most candidates gave their final answer to an appropriate number of significant figures and gave the correct sign for ΔH .
- (d) The majority of candidates received full credit for this section but a few did not repeat the experiment with **FA 5** or gave headings that were ambiguous for their results. Candidates should be advised to read through a question and to prepare a table for all the results they are told to obtain before starting any practical work.
- (e) Almost all candidates who carried out the experiment with both **FA 4** and **FA 5** gained credit for (i) and (ii). Most candidates successfully calculated the numbers of moles of copper(II) sulfate and magnesium used in (iii). However, some stopped there and did not go on to show that the copper(II) sulfate was in excess. Good answers referred to the equation for the reaction and/or the mole ratio of the reactants.
- (f) 'Show clearly how you obtained your answer' was ignored by many. However, many candidates drew suitable Hess' cycle diagrams or showed the equation for **Reaction 2** reversed. A greater number of candidates successfully calculated the enthalpy change for **Reaction 3**.
- (g) Some excellent answers to both parts were seen, indicating that some Centres had spent time in discussing errors and improvements. Many candidates had the right idea in (i), stating that the graphical method was more accurate but they did not go on to connect this to dealing with heat loss. More candidates gained credit in (ii) for connecting greater volume with smaller ΔT but many stopped at stating that copper(II) sulfate was already in excess or there would be no difference in outcome.

Question 2

- (a) Some candidates only stated two nitrogen-containing ions in (i) with NH_4^+ being most frequently missed. Most candidates incorrectly suggested warming the unknown, **FA 6**, with aluminium and aqueous sodium hydroxide; this would give a positive result with all three possible ions and was not therefore suitable to distinguish between them. Candidates should always name any acid chosen as a reagent.

The observations recorded in (ii) were generally good though a minority claimed red litmus turned blue on warming the unknown with aqueous sodium hydroxide suggesting the litmus went into the solution rather than testing any gas evolved. Candidates need to ensure clarity of their work, for example, some seemed to add the acid to the tube containing **FA 6** plus aluminium and sodium hydroxide. Some candidates had sufficient observations when testing the ions suggested in (i) to come to a correct conclusion in (iii). However, some concluded nitrate without carrying out sufficient tests for this ion.

- (b) A large number of candidates recorded a correct observation in the first test and many gained full credit for the second test. The most frequent errors were recording a cream or green precipitate with **FA 7** plus aqueous potassium iodide or a brown precipitate or solution when testing with glucose. However, many obtained the expected silver mirror in the third test.
- (c) Many candidates gained at least half of the credit available here. The most frequently awarded marking point was in (i) for **FA 8** turning yellow on heating. Many candidates did not realise that the instruction 'leave to cool' indicated a further observation should be made. Many candidates reported effervescence/fizzing/bubbling in (ii) but far fewer went on to test the gas. Some reported 'a gas was evolved' which is a conclusion rather than an observation. It is possible that some candidates did not realise in (iii) and (iv) that a large excess of alkali would need to be added. **FA 8** was reacted with nitric acid to put the cation into solution so any acid remaining needed to be neutralised before the cation would form a precipitate and even more alkali needed to be added to

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have excess present. The majority of candidates correctly concluded CO_3^{2-} but fewer were able to identify the cation as Zn^{2+} .

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key Messages

- The reading of scales on apparatus and the recording of the readings must be to a suitable level of precision. Thermometer readings should be recorded to the nearest 0.5 °C and burette readings to 0.05 cm³.
- The plotting of points on graphs and drawing lines of best fit requires the use of a sharp pencil and a long ruler. Points should be plotted precisely and all plotted data should occupy over half the grid in either direction. Straight lines of best fit should be drawn using a ruler and there should be an even distribution of points on either side of the line with any anomalies clearly labelled.
- Errors and improvements should be discussed when carrying out quantitative practical work during the course.
- Conclusions and inferences must be drawn from the actual results of tests carried out and are different from observations.
- Instructions in the rubric need to be read and acted upon.

General Comments

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This paper proved accessible to most candidates and a wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

- (a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. A significant minority of candidates (and Supervisors) did not record accurate burette readings to 0.05 cm³ or did not have concordant titres. Some candidates were clearly better prepared for carrying out and recording the titration exercise than others. It is important that the Supervisor carries out the experiment using the same solutions as the candidates.
- (b) Almost all candidates calculated a suitable value for the volume of **FB 4** to be used in the calculation with few selecting titres with a spread of more than 0.20 cm³. Candidates generally indicated which titres they used in their calculation.
- (c) Almost all candidates gained credit in (i) for calculating the number of moles of potassium manganate(VII) reacting and a large majority also balanced the equation correctly in (ii). Almost all candidates successfully used the mole ratio from their equation to calculate the number of moles of hydrogen peroxide in (iii). However, many did not refer back to the capacity of the pipette used in

the titration for the answer to (iv) or use the dilution factor for (v). Many candidates correctly supplied all their final answers to 3 or 4 significant figures.

Question 2

- (a) Almost all candidates carried out the four experiments and gained credit for the table of results though a few did not calculate ΔT correctly. A substantial number of candidates did not record the temperatures to .0 °C or .5 °C and so could not be awarded credit for precision of readings. A large majority of candidates achieved increasing values for ΔT . As with the titration, it is important that the Supervisor uses the same solution on the same day as the candidates.
- (b) Almost all candidates labelled the axes correctly though a number chose scales that did not occupy over half the available space and a few plotted maximum temperature rather than ΔT . The plotting was generally good though some candidates were imprecise in the placing of points and some used large blobs that were not centred in the correct position to denote points. A few used such faint pencil marks that it was difficult for Examiners to read them. Those choosing to use difficult scales such as 3 °C to one large square tended to be inaccurate in their plotting. Few candidates used (0,0) even though this was a valid plot point. Many gained credit for the line of best fit even if the origin was not used.
- (c) Only a minority of candidates was able to calculate the gradient of their line of best fit from a suitably-sized triangle on the graph in (i). Others incorrectly averaged the rise in temperature for the four experiments. Few candidates used the volume of solution heated rather than the volume of hydrogen peroxide reacting in the calculation in (ii). A far greater proportion of candidates gained credit in (iii) with some successfully using the default value given in the question. Of those attempting (iv) many received credit but some did not convert J to kJ or wrote ΔH instead of a negative sign in the answer.
- (d) Most candidates gaining credit here did so by correctly identifying an anomalous result from the graph. Some correctly identified the experiment likely to have the greatest error but did not go on to justify their choice.

Question 3

Candidates should be reminded to use the Qualitative Analysis Notes. Many candidates who successfully identified iodide ions in **FB 7** in (a) did not appear to use this information in (b).

- (a) Many candidates struggled to identify iron(II) here. However, many realised that warming the mixture indicated a need for testing any gas with damp red litmus paper and achieved credit for this.

Candidates need to make sure that their answers are to a suitable degree of precision. In (ii), some did not note the effervescence while others did not state that it was the precipitate changing colour. However, many had sufficient correct observations and a valid explanation to receive credit for the type of reaction. Only a small number of candidates tested the gas evolved and some of those mistakenly reported the gas turning limewater milky. The majority of candidates reported the expected observations in (iii) though some only gave the final colour rather than both colour changes. Only a minority of candidates wrote 'not known' for the cation in **FB 7** though most identified iodide correctly.

- (b) Candidates need to be reminded that they should test gases evolved during a reaction. While many correctly reported effervescence with magnesium ribbon and **FB 8**, far fewer tested the gas with a lighted splint. Not all candidates noted the black precipitate or coating on the ribbon with **FB 9**. Most candidates correctly reported no reaction with **FB 7** + **FB 8**. However, the colours of the two precipitates also had to be correct in order for credit to be awarded here. Many candidates described this precipitate as cream though more reported the correct colour with **FB 8** reacting with **FB 9**. Few candidates were able to use their observations to identify the cation in **FB 9** in (ii) but those who were successful generally gave a correct ionic equation in (iii). Again, few candidates were able to identify both ions present in **FB 8** though some correctly identified either Cl^- or H^+ .

CHEMISTRY

Paper 9701/35

Advanced Practical Skills 1

Key Messages

- The reading of scales on apparatus and the recording of the readings must be to a suitable level of precision. In this paper this means that thermometer readings should be recorded to the nearest 0.5 °C, burette readings to 0.05 cm³ and balance readings should be to a consistent number of decimal places.
- Errors and improvements are a feature of this syllabus and should be discussed when carrying out quantitative practical work during the course.
- Conclusions and inferences must be drawn from the actual results of tests carried out and are different from observations.
- Instructions in the rubric need to be read and acted upon.

General Comments

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This paper proved accessible to most candidates and a wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

- (a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Most candidates gave correct headings and units. However, there is still a significant minority of candidates (and Supervisors) who do not record accurate burette readings to 0.05 cm³ or do not have concordant titres i.e. two results within 0.1 cm³ of each other. It is important that the Supervisor carries out the experiment using the same solutions as the candidates.
- (b) Almost all candidates obtained a suitable value of the volume of **FA 2** to be used in the calculation with few selecting titres with a spread of more than 0.20 cm³. Candidates generally indicated which titres they used – either by ticking the values in the results table or showing a calculation.
- (c) Almost all candidates gained credit in (i) for calculating the number of moles of nitric acid reacting but a significant number either omitted (ii), omitted the state symbols or did not attempt to balance the equation. A large number of candidates recognised that for (iii) it was necessary to divide (ii) by 2 and for (iv) it was necessary to multiply (iii) by 10. In part (v) however many did not recognise that the solution had been diluted by a factor of 10. This meant that the M_r they calculated was very large but correct calculation of the value of x , from this M_r , was credited.

- (d) Many candidates answered this correctly.

Question 2

- (a) Since the rubric of the question stated exactly which readings should be recorded and what calculations should be included it was necessary to have 6 values in the table. Care must be taken with headings and units since, for example, 'weight' is not acceptable when 'mass' is being recorded.
- (b) Most candidates were evidently aware of the formula needed to calculate the energy produced but a significant minority used the mass of solid rather than that of the solution in (i). Most could also calculate the number of moles in (ii) and hence the enthalpy change in (iii). However a number of candidates gave an incorrect sign for this change or did not convert J to kJ.
- (c) (d) Since the skills needed were similar to those needed in (a) and (b) outcomes were also similar and candidates generally showed that they were familiar with this type of calculation.
- (e) This part however proved challenging since although most candidates realised that they needed to use their answers to (d)(iii) and (b)(iii) in some way, many did not use them correctly and very few showed how they obtained an answer. Once again this shows the importance of reading the rubric in the question.
- (f) Answers based on agreeing or not agreeing with the student's suggestion were acceptable but a reason, with chemical validity, had to be given to support the statement.

Question 3

Although many candidates gave good answers to this question, some appeared to have made limited use of the Qualitative Analysis Notes. Candidates should be encouraged to read through the question before starting any practical work – perhaps underlining important information and thinking about the reactions associated with a named reagent. Precise observations are essential and candidates must investigate the effect of adding excess of reagents.

- (a) Very few candidates were awarded full credit in this section. A number of candidates did not add excess sodium hydroxide and ammonia and a number did not apparently recognise the use of silver nitrate followed by aqueous ammonia as being the test for halide ions. In a test such as the latter the Qualitative Analysis Notes are useful in that they link the precise colour of precipitate with its possible solubility in ammonia.
- In (iv) the lack of addition of excess sodium hydroxide and ammonia or incorrect observations of these tests lead to many incorrect identifications of the cation in **FA 7**. Identification of the anions was generally more successfully accomplished although some confusion with the halide ions and sulfite/sulfate was noted.
- (b) In (i) there are many possible observations that can be made and these were credited so that most candidates gained at least partial credit. In (ii) many candidates realised that aqueous sodium hydroxide should be used and many observed the green precipitate to conclude the presence of Fe^{2+} . Very few however heated the mixture produced to test for ammonia and thus prove the presence of NH_4^+ .

CHEMISTRY

Paper 9701/36

Advanced Practical Skills 2

Key Messages

- The reading of scales on apparatus and the recording of the readings must be to a suitable level of precision. In this paper this means that burette readings should be recorded to 0.05 cm^3 and times should, as instructed in the question, be quoted to the nearest second.
- Errors and improvements are a feature of this syllabus and should be discussed when carrying out quantitative practical work during the course.
- Conclusions and inferences must be drawn from the actual results of tests carried out and are different from observations.
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Comments on Specific Questions

Question 1

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- (b) Almost all candidates obtained a suitable value of the volume of **FB 1** to be used in the calculation with few selecting titres with a spread of more than 0.20 cm^3 . Candidates generally indicated which titres they used – either by ticking the values in the results table or showing a calculation.
- (c) Almost all candidates gained credit in (i) for calculating the M_r of KIO_3 but a number did not use the 3.60 g quoted in the stem of the question or did not divide by 40 to recognise that 25 cm^3 of **FB 2** were being considered. In (ii) a significant number apparently used only one of the two equations given so that they multiplied by 2 or 3 (rather than by 6). Apart from a few who used 25.0 cm^3 , rather than the volume from (b) in the calculation, (iii) was generally correct.

Question 2

- (a) Each candidate's competence in carrying out the practical procedure specified was judged by comparing their reaction times; the time using 10 cm³ of **FB 5** should be twice that using 20 cm³. Many candidates were within acceptable limits for this and received credit accordingly.
- (b) Candidates were told not to use volumes of **FB 5** that were less than 5 cm³ and they should also have realised that the volumes chosen should be across the whole range available; that no two volumes should be too close together.
- The rubric also stated that reaction times should be recorded to the nearest second and a significant number of candidates quoted times to a higher degree of accuracy.
- (c) Since the rubric of the question stated exactly which readings should be recorded it was necessary to show all these data.
- (d) Suggestions of either agreement or lack of agreement could both be credited if the conclusion was clearly based on the experimental evidence. It was expected that the product of volume of **FB 5** and reaction time would be approximately constant but if the candidate considered that this was not the case, credit could be awarded for a suitable explanation.
- (e) Although many candidates stated that the thiosulfate would be in excess, few went on to link that to the fact that all the iodine produced would be reduced so that none would be available to react with the starch.
- (f) Many candidates recognised that it was necessary to alter the volume of **FB 5** but fewer included the need to keep the total volume of **FB 4** and water constant.

Question 3

Although many candidates gave good answers to this question, some appeared to have made limited use of the Qualitative Analysis Notes. Candidates should be encouraged to read through the question before starting any practical work – perhaps underlining important information and thinking about the reactions associated with a named reagent. Precise observations are essential and candidates must investigate the effect of adding excess of reagents.

- (a) Very few candidates were awarded full credit in this section since observations were often incomplete. In (ii) it was necessary to include the formation of the off-white precipitate **and** its darkening on standing and in (iii) the fizzing noted by many had to be tested to relight a glowing splint. In (iv) both the initial and final colours were required.
- (b) Many candidates recognised that manganese was present in both **FB 7** and **FB 8**.
- (c) As in (a), candidates need to ensure that their observations are complete. Most candidates observed **FB 9** going black in (i) but many did not note the effervescence **and** the formation of the blue solution in (ii). In (iii) a variety of observations were acceptable but many candidates limited their answer to a single one. The change in colour, towards yellow, was noted by many in (iv) and a significant number also recognised the presence of the copper ion in (v) and the change in oxidation state in (vi) although this was occasionally reversed.
- (d) Some correct answers were seen but a number of answers showed they did not understand the significance of various parts of the Periodic Table since responses based on specific groups or periods were seen.

CHEMISTRY

<p>Paper 9701/41 A2 Structured Questions</p>
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Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Candidates are reminded of the importance of careful, thorough reading of the question before attempting to answer.
- Candidates should set out calculations with clear explanations of the numbers involved. This is especially important where Examiners are able to apply credit for error carried forward.
- Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A Level examination.

General Comments

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

Candidates are reminded to make sure that their desired final answers are legible and obvious to the Examiner.

Comments on Specific Questions

Question 1

- (a) (i) Most candidates gained at least partial credit for giving the correct orders with respect to reactants but some did not refer to data in table, as required by the question.
- (ii) Many candidates carried out the calculation correctly, although many ignored the need for two significant figures, as required by the question.
- (iii) Most candidates were able to give a correct equation.
- (iv) Many candidates carried out the calculation correctly giving the correct units of k . A common error was k being calculated using incorrect experimental data.
- (b) Most candidates gained at least partial credit here, though the shape and clarity of many curves needed to be improved. Many candidates needed to be more precise with their explanations.
- (c) Many candidates did not realise that the orders suggested that one molecule of F_2 and one molecule of NO were involved in the rate determining slow step.

Question 2

- (a) This question was not well answered, with many candidates not applying the rules of orbital occupancy for the nickel atom. For the formation of the ion, some candidates incorrectly removed d electrons.
- (b) (i) Many candidates gave the correct answer here.
- (ii) There were some good answers, although many candidates did not recall that lower energy d orbitals have each of the lobes pointing between two of the axes or that higher energy d orbitals have their lobes pointing along the axes.
- (c) Most candidates gained credit here. Some candidates did not describe the promotion of an electron from a lower to a higher level by the absorption of visible light, or the colour transmitted (not emitted) being the complement of the colour absorbed.
- (d) Many candidates gained partial credit here using their knowledge of Cu^{2+} chemistry to answer this question. **A** was $\text{Ni}(\text{OH})_2$ and both 4-coordinated and six-coordinated complexes of **B** were credited. A common error was unbalanced equations.

Question 3

- (a) (i) Many candidates correctly identified the isotopic composition of the three fragments.
- (ii) This was generally well answered. The most common error was the relative ratio of 9:3:1.
- (b) (i) Almost all candidates gave the correct answer here.
- (ii) Many candidates answered correctly here. The octahedral sketch was generally better drawn than the tetrahedral one. Some candidates incorrectly displayed a square planar sketch for $[\text{PCl}_4]^+$.
- (c) (i) A pleasing number of candidates correctly identified one of the variations. Common errors were phosphorus with four bonds or oxygen with three bonds.
- (ii) Almost all gave the correct answer here.
- (d) (i) Many candidates gave a correct expression for K_{sp} here. Common errors were incorrect charges on the ions and the powers of concentration.
- (ii) Although 'error carried forward' from (i) was used, it was unusual for candidates to be awarded more than partial credit. A common error was incorrect calculation of the concentrations of the two ions. Many candidates gained credit for their units.
- (e) (i) Most candidates gave the correct definition of the lattice energy. Weaker answers involved the description of a mole of ionic compound being formed from 1 mole of its gaseous ions.
- (ii) Many candidates managed to suggest a valid reason here.

Question 4

- (a) (i) This was generally well answered, although there were many incorrect or unbalanced equations.
- (ii) Most candidates gained at least partial credit here. The direction and source of curly arrows proved problematic as did the drawing of the intermediate.
- (b)(i)(ii) The explanation required here should have been learnt. Whilst the majority of candidates knew that ethanoic acid was less acidic than chloroethanoic acid, and that ethanol was less acidic than phenol, many did not relate these acidities to valid explanations.

- (c) Many candidates seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus here. The type of reaction with Na and the reaction with hot excess NaOH(aq) proved difficult.

Question 5

- (a) Candidates should be aware of the relative rate of hydrolysis of these organohalogen compounds. Although some candidates gave the correct order of hydrolysis, the explanation in terms of C-Cl bond strength was not always given.
- (b) Most candidates identified the correct functional groups here but should note that vague terms such as carbonyl or carboxylic are not detailed enough for credit to be awarded.
- (c) (i) Again, candidates need to be sure of the methods used for drawing curly arrows in such a reaction mechanism.
- (ii) Many candidates were able to give the correct mechanism.
- (iii) Most candidates correctly identified HBr. However CH₃Br was a common incorrect answer.
- (d) Most candidates gained at least partial credit here. **W** and **Y** were more commonly correct than **X**. Candidates need to take care when drawing structures to avoid mistakes. **X** was often incorrectly drawn as an ester.
- (e) Candidates should be reminded to read the question. Here they were asked to give **two** repeat units; this was very often not seen.

Question 6

- (a) This was generally well answered by candidates.
- (b) (i) Many candidates did not recognise a solvent was required for the mobile phase or Al₂O₃ (or SiO₂) for the stationary phase. A common error was confusing this technique with column chromatography or electrophoresis.
- (ii) Candidates gave mixed answers here. Partition was a common error.
- (c) Most candidates gained some credit here although often did not concentrate on structural aspects of DNA.
- (d) Many candidates answered this question well.

Question 7

- (a) Candidates were asked to circle the bonds that could be easily hydrolysed but many circled the functional groups instead.
- (b) Many candidates were able to give a correct answer here.
- (c) This was answered well by candidates.
- (d) Almost all candidates gave the correct answer here.

Question 8

- (a) (i) The calculation of the number of carbon atoms was carried out successfully by most candidates.
- (ii) A good number of candidates correctly stated the molecular formula of **T**, although a common error was C₄H₉OH.

- (b) (i) Some candidates managed to correctly identify the structure of **T**. Many incorrectly suggested butan-2-ol.
- (ii)(iii) Most candidates gained at least partial credit here. Candidates were required to identify the type of proton responsible for each of the absorptions in **T** and to do this should have consulted the *Data Booklet*. From some of the answers given it did not seem likely that candidates had used their *Data Booklets*.
- (iv) Many candidates identified that the OH peak would not be present in D₂O.

CHEMISTRY

<p>Paper 9701/42 A2 Structured Questions</p>
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Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Candidates are reminded of the importance of careful, thorough reading of the question before attempting to answer.
- Candidates should set out calculations with clear explanations of the numbers involved. This is especially important where Examiners are able to apply credit for error carried forward.
- Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A Level examination.

General Comments

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

Candidates are reminded to make sure that their desired final answers are legible and obvious to the Examiner.

Comments on Specific Questions

Question 1

- (a) (i) Most candidates gained at least partial credit for giving the correct orders with respect to reactants but some did not refer to data in table, as required by the question.
- (ii) Many candidates carried out the calculation correctly, although many ignored the need for two significant figures, as required by the question.
- (iii) Most candidates were able to give a correct equation.
- (iv) Many candidates carried out the calculation correctly giving the correct units of k . A common error was k being calculated using incorrect experimental data.
- (b) Most candidates gained at least partial credit here, though the shape and clarity of many curves needed to be improved. Many candidates needed to be more precise with their explanations.
- (c) Many candidates did not realise that the orders suggested that one molecule of F_2 and one molecule of NO were involved in the rate determining slow step.

Question 2

- (a) This question was not well answered, with many candidates not applying the rules of orbital occupancy for the nickel atom. For the formation of the ion, some candidates incorrectly removed d electrons.
- (b) (i) Many candidates gave the correct answer here.
- (ii) There were some good answers, although many candidates did not recall that lower energy d orbitals have each of the lobes pointing between two of the axes or that higher energy d orbitals have their lobes pointing along the axes.
- (c) Most candidates gained credit here. Some candidates did not describe the promotion of an electron from a lower to a higher level by the absorption of visible light, or the colour transmitted (not emitted) being the complement of the colour absorbed.
- (d) Many candidates gained partial credit here using their knowledge of Cu^{2+} chemistry to answer this question. **A** was $\text{Ni}(\text{OH})_2$ and both 4-coordinated and six-coordinated complexes of **B** were credited. A common error was unbalanced equations.

Question 3

- (a) (i) Many candidates correctly identified the isotopic composition of the three fragments.
- (ii) This was generally well answered. The most common error was the relative ratio of 9:3:1.
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- (c) (i) A pleasing number of candidates correctly identified one of the variations. Common errors were phosphorus with four bonds or oxygen with three bonds.
- (ii) Almost all gave the correct answer here.
- (d) (i) Many candidates gave a correct expression for K_{sp} here. Common errors were incorrect charges on the ions and the powers of concentration.
- (ii) Although 'error carried forward' from (i) was used, it was unusual for candidates to be awarded more than partial credit. A common error was incorrect calculation of the concentrations of the two ions. Many candidates gained credit for their units.
- (e) (i) Most candidates gave the correct definition of the lattice energy. Weaker answers involved the description of a mole of ionic compound being formed from 1 mole of its gaseous ions.
- (ii) Many candidates managed to suggest a valid reason here.

Question 4

- (a) (i) This was generally well answered, although there were many incorrect or unbalanced equations.
- (ii) Most candidates gained at least partial credit here. The direction and source of curly arrows proved problematic as did the drawing of the intermediate.
- (b)(i)(ii) The explanation required here should have been learnt. Whilst the majority of candidates knew that ethanoic acid was less acidic than chloroethanoic acid, and that ethanol was less acidic than phenol, many did not relate these acidities to valid explanations.

- (c) Many candidates seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus here. The type of reaction with Na and the reaction with hot excess NaOH(aq) proved difficult.

Question 5

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- (b) Most candidates identified the correct functional groups here but should note that vague terms such as carbonyl or carboxylic are not detailed enough for credit to be awarded.
- (c) (i) Again, candidates need to be sure of the methods used for drawing curly arrows in such a reaction mechanism.
- (ii) Many candidates were able to give the correct mechanism.
- (iii) Most candidates correctly identified HBr. However CH₃Br was a common incorrect answer.
- (d) Most candidates gained at least partial credit here. **W** and **Y** were more commonly correct than **X**. Candidates need to take care when drawing structures to avoid mistakes. **X** was often incorrectly drawn as an ester.
- (e) Candidates should be reminded to read the question. Here they were asked to give **two** repeat units; this was very often not seen.

Question 6

- (a) This was generally well answered by candidates.
- (b) (i) Many candidates did not recognise a solvent was required for the mobile phase or Al₂O₃ (or SiO₂) for the stationary phase. A common error was confusing this technique with column chromatography or electrophoresis.
- (ii) Candidates gave mixed answers here. Partition was a common error.
- (c) Most candidates gained some credit here although often did not concentrate on structural aspects of DNA.
- (d) Many candidates answered this question well.

Question 7

- (a) Candidates were asked to circle the bonds that could be easily hydrolysed but many circled the functional groups instead.
- (b) Many candidates were able to give a correct answer here.
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- (d) Almost all candidates gave the correct answer here.

Question 8

- (a) (i) The calculation of the number of carbon atoms was carried out successfully by most candidates.
- (ii) A good number of candidates correctly stated the molecular formula of **T**, although a common error was C₄H₉OH.

- (b) (i) Some candidates managed to correctly identify the structure of **T**. Many incorrectly suggested butan-2-ol.
- (ii)(iii) Most candidates gained at least partial credit here. Candidates were required to identify the type of proton responsible for each of the absorptions in **T** and to do this should have consulted the *Data Booklet*. From some of the answers given it did not seem likely that candidates had used their *Data Booklets*.
- (iv) Many candidates identified that the OH peak would not be present in D₂O.

CHEMISTRY

Paper 9701/43
A2 Structured Questions

Key Messages

- Candidates are reminded of the importance of careful, thorough reading of the question before attempting to answer it.
- Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination.

General Comments

This examination paper produced many excellent candidate scripts, which were characterised by good factual knowledge and the ability to apply knowledge and understanding to novel situations.

Question 1

- (a) Many found this question difficult. A surprising number of candidates wrote the formulae of chloroalkanes in column two, instead of isotopes of chlorine. Most candidates omitted the positive charge.
- (b)(i) Those who knew strontium chloride was ionic usually got this right. A surprising number of covalent diagrams were seen, along with many ambiguous diagrams.
- (ii) Most candidates gained at least partial credit here.
- (c)(i) This was often not well answered. Many candidates gave $\text{SrCO}_3 + \text{NaNO}_3$, which cannot be used to make this soluble salt. Of those who correctly chose to use $\text{SrCO}_3 + \text{HNO}_3$ a significant number gave H_2CO_3 as a second product rather than $\text{CO}_2 + \text{H}_2\text{O}$.
- (d) This was done well by most candidates, full credit often being awarded. However, even in good answers the third marking point was sometimes missed, such answers not making it clear that it is the anion/nitrate ion that is distorted or polarised by smaller cations such as Mg^{2+} .

Question 2

- (a) The most common error was to balance the species without attempting to balance the charges, giving $\text{BrO}_3^- + \text{Br}^- + 6\text{H}^+ \rightarrow \text{Br}_2 + 3\text{H}_2\text{O}$, which gained partial credit. Some candidates attempted to balance such equations by adding electrons on the right hand side which was not acceptable.
- (b)(i) This was generally well done, although some candidates gave three correct orders without showing their reasoning and thus only partial credit could be awarded. This emphasises the importance of reading the examination paper carefully.
- (ii) This was generally well done, although a few rate equations did not have a k , or began $k =$.
- (iii) Many candidates gave correct answers here. A few candidates ignored the instruction to use experiment 1 to calculate k . Some candidates gave units which were missing s^{-1} or with dm^{-9} .

Question 3

- (a) (i) This piece of factual knowledge was known by approximately half of all candidates.
- (ii) This piece of factual knowledge was known by far fewer candidates. The most common error was to say that degenerate means “split into different energy levels”.
- (iii) Many candidates identified the dz^2 as a higher energy orbital, but fewer identified the dx^2-y^2 .
- (b) (i)(ii) This question discriminated well, the formulae of **A**, **B** and **C** and the colours of **B** and **C** being pieces of factual knowledge that need to be learned.
- (iii) Many candidates referred to oxidation or reduction rather than redox. In an organic reaction an answer such as oxidation or reduction is often acceptable as it can sometimes be assumed to refer to the organic reactant, but this assumption cannot be made in this case where all species are inorganic. Various incorrect answers for the role of copper metal were seen, such as ligand exchange and oxidising agent.
- (c) A surprising number of candidates thought that copper was not a transition element, or stated that because there were no ligands co-ordinated to the metal, the d orbitals did not split. One unfortunate but quite common error was to describe Cu^+ as having “a full d orbital”. This term can equally be applied to Cu^{2+} . Candidates should have described Cu^+ as having “a full d subshell”.
- (d) A significant few mistook the absorbance at red and blue as the colour that would be seen. Some candidates mentioned the absorbance of only red or blue instead of both. It was not enough to say “green is not absorbed” since this is also true of white objects.

Question 4

- (a) Most candidates appreciated the significance of HCl being a “stronger acid” or “more dissociated”. Fewer candidates related the strength of acid to the higher concentration of ions, instead referring to more electrons flowing through the wires. While this answer is true it was considered to be an insufficient response. Some candidates referred to electrode potentials and others to the chloride ion’s electron withdrawing effect.
- (b) (ii) Many correct answers were possible here, and many were seen. Many candidates suggested $NaOH$ but did not recognise that an excess of ethanoic acid was required compared to the amount of $NaOH$ added. Some candidates did not recognise the need for a “named base” and suggested adding “a base” or “hydroxide”.
- (c) This question discriminated well. Correct answers all began with either $CH_3CH(NH_2)CO_2H$ or $CH_3CH(NH_3^+)CO_2^-$. A significant number of incorrect answers began with $CH_3CH(NH_2)CO_2^-$ or $CH_3CH(NH_3^+)CO_2H$, however these species will be in low concentration in a solution of alanine.
- (d) (i) Very few correct answers were seen here. Overall, candidates found this the most difficult question on the paper. Many equations were seen in which a tartaric acid molecule ionised to give a $2-$ ion and two H^+ ions. This showed incorrect understanding of the dissociation constant.
- (ii) A pleasing number of candidates gained full credit here. The most common errors were:
- to redraw the structure in the question,
 - to draw structural isomers not stereoisomers,
 - to draw a structure in which one or both ends of the molecule was rotated but not different,
 - to draw two identical structures.

Question 5

- (a) Candidates were not confident in their knowledge of the bonding and shape of benzene. It was hoped that candidates would show the circles of π electron density above and below the plane of the ring, which some did. A surprising number of candidates described the Kekulé structure. Some candidates described the reactivity of benzene, rather than the bonding and shape.

- (b) Many candidates made a reasonable attempt at this question, being awarded at least half the credit available.
- **X** was often given correctly as Na or NaOH and correct structures were drawn.
 - **Y** was less often correct, but HCl or Na₂CO₃ followed by correct structures was seen on many scripts.
 - **Z** was least often correct. Candidates who chose 2,4-DNPH often found the structure of the product difficult to draw correctly. Candidates who chose an oxidising agent such as Cr₂O₇²⁻/H⁺ or Tollens' reagent were most likely to gain credit.

Question 6

- (a) (i) While this was straightforward it required a good understanding of skeletal formulae and of the benzene ring.
- (ii) Despite there being only one chiral centre present, a few candidates circled more than one atom.
- (iii) Some candidates did not read "in addition to the aryl" group and listed benzene as a functional group. The most common errors were to give amide instead of amine and to give carbonyl instead of ketone.
- (b) This question required some standard pieces of factual knowledge, but the novel context of methoxetamine made it difficult for many.

In (ii), care and precision were required; one H and a plus charge should have been added to the nitrogen atom. Many answers were seen where either the H or the plus charge were added, but not both.

In (iii) the correct structure of the product was most clearly shown by candidates who chose to do partly displayed formulae. Some candidates who chose other approaches often gave ambiguous structures such as -CH₃CONCH₂CH₃ or -NCH₃COCH₂CH₃.

Question 7

- (a) Partial credit was most commonly awarded because candidates often omitted a reference to equilibrium.
- (b)(c) These questions were demanding but it is pleasing to note the significant number of candidates gaining full credit.
- (d) (i) Most candidates correctly wrote "the solvent" or named a suitable solvent such as water or ethanol. Some candidates wrote "the water between the cellulose fibres" which was not acceptable.
- (ii) Several descriptions such as "non-volatile oil" were acceptable but they were rarely seen.
- (iii) Many candidates knew that 1 was *R_f* or retardation factor, fewer candidates knew that 2 was retention time. However credit was often awarded for a correct description of timing that did not use the term "retention time".
- (e) Most candidates gained credit here.

Question 8

- (a) This was correctly answered by most candidates.
- (b) Candidates seemed to have difficulty making their answers clear in (i).

Many candidates gained credit in (ii) for knowing that the other optical isomer might be toxic, or give side effects, or be harmful in some other reasonable way.

- (c) (i) This question discriminated well. Many candidates drew four clear diagrams of the different aldehydes. Common errors were
- drawing ketones not aldehydes,
 - drawing aldehydes that had alkene groups and therefore were not $C_5H_{10}O$,
 - drawing the same aldehyde more than once.
- (ii)(iii) A significant number of candidates stated that $CH_3(CH_2)_3CHO$ has two absorptions; they did not appreciate the different environments in the $CH_3(CH_2)_3$ chain.

Question 9

- (a) This piece of factual knowledge was known by few candidates.
- (b) This was answered well by many candidates although errors included
- drawing only one repeat unit,
 - using the single monomer $H_2NC_6H_4CO_2H$,
 - drawing the side groups 1,4 on each benzene ring, not 1,3,
 - missing hydrogen atoms in the amide links,
 - drawing some correct amide links but drawing others with $-O-$ bonds.
- (c) Many candidates answered this correctly. However, a significant number stated that “the primary structure is the peptide link”, which did not receive credit.
- (d) Most candidates gained credit for “hydrogen bond”, but few actually drew a correct hydrogen bond. Where the question states “use the diagram” this should always be done in the answer.
- (e) These pieces of factual knowledge were known by only a minority of candidates. Some candidates gave answers that restated the question e.g. “heating to $70^\circ C$ would denature an enzyme” without explaining how.

CHEMISTRY

Paper 9701/51

Planning, Analysis and Evaluation

Key Messages

The introduction to a question provides important guidance to help candidates understand the experiment that follows. They should not attempt to answer questions until this information has been absorbed.

Sufficient practice using class experiments throughout the year is required if convincing answers are to be provided to questions based on the analysis and evaluation of experiments.

Care is needed to avoid simple errors when writing formulae or carrying out calculations.

General Comments

Question 1 was based partly on practical work examined at AS level. However, many candidates were not confident in these reactions. For this reason candidates found **(a)** and **(b)** particularly demanding.

Question 2 was tackled more successfully and candidates could generally draw the graph and identify the anomaly. Despite the experiment being based on a pH titration procedure, few were able to demonstrate an understanding of the shape of the graph. In **(e)** and **(f)** candidates often tried to apply formulae that were not relevant to the calculation they were attempting. It is worth noting that the Examiners allowed for errors carried forward from one part to the next and on that basis credit was often obtained. A particularly common error in **(d)(i)** was the belief that hydroxide ions were still present in significant quantities once sodium hydroxide had been added to the acid. The misunderstanding appeared to be that because the acid was weak only a small number of hydrogen ions would be neutralised.

Comments on Specific Questions

Question 1

- (a)** Unexpected difficulties were found by those candidates who thought that copper reacted with dilute sulfuric acid or that zinc hydroxide and aluminium hydroxide would be obtained as solutions. Some candidates seemed to have not absorbed the information given in the introduction.
- (b)** Good credit was generally obtained by candidates who had established a clear strategy in **(a)**. However, only a few were able to provide clear reasons for their choices.
- (c)** Many candidates were able to correctly explain that the hydroxides needed heating until constant mass was achieved though some also stated "until no more gas was evolved". Even if steam was identified as the gas this would not be sufficiently reliable.
- (d)** It was surprising that having been guided to obtain the oxides in **(c)** many candidates were unable to provide the correct answer to this question. To obtain a correct mass of copper it should be washed with water (or propanone) and dried. Some candidates suggested electrolysis of the sample which would not be feasible with a precipitate.
- (e)** Many candidates used an incorrect formula for aluminium oxide. Another common error was to forget when calculating the mass that there are two moles of aluminium ions in one mole of aluminium oxide.
- (f)** Few candidates recognised that the small amount of copper in the sample meant that it would be difficult to obtain an accurate mass for it. Many answers mistakenly suggested that the problem

would stem from the high reactivity of copper or the assumption that copper would dissolve in sulfuric acid.

Question 2

- (a) Most candidates plotted the points on the graph reliably although they should be reminded that a point should be indicated using a sharp pencil to allow for precision. It was difficult to draw a curve through the points and the Examiners accepted any that were reasonably close. It had been expected that candidates would be familiar with the experiment and therefore draw a vertical line at the end-point of the reaction but this was not required for credit to be awarded.
- (b) Credit was awarded for the anomalous point(s) based on the curve that had been drawn. Most candidates gained credit but a few did not because they identified a point as being anomalous even though the curve they had drawn went through the point. A correct reason for the anomaly was also given by the majority of candidates, most opting for an explanation based on the suggestion that an incorrect volume of sodium hydroxide had been added.
- (c) A suitable indicator range was correctly identified by many candidates although several wanted to extend the lower range of pH values to 4 or 5 or beyond 11 in the upper range. Some candidates did not read the question carefully and opted to name an indicator rather than a pH range.
- (d) (i) It was clear that candidates did not always understand the process of the titration. A surprising number included the hydroxide ion amongst the ions present in highest concentration. Others did not appreciate that as NaA was generated in the titration, the sodium ion and A^- ion would be present in comparatively large amounts.
- (ii) Candidates struggled to explain how the concentrations of the species in the question compared.
- (e) The vast majority read the graph correctly, gaining credit, but there were instances of incorrect readings. Further credit was available for a statement of K_a either directly or in its logarithmic form. A few candidates went on to gain full credit by recognising that in this mixture at the mid-point of the titration $[HA] = [A^-]$.
- (f) (i) It is important to emphasise to candidates that if they are uncertain of an answer to a previous part they should continue as Examiners will always allow an error carried forward. This was particularly relevant to this question where a significant number of candidates achieved full credit despite an incorrect value for K_a .
- (ii) Some left this part unanswered. Candidates needed to use their answer from (f)(i) and the mass of HA used to calculate a value for the relative molecular mass of the acid.
- (g) By far the most frequently seen answer was that, since HA was weak, it would not fully react with the sodium hydroxide. This represents a misunderstanding which perhaps also accounts for the erroneous answers to 2(d)(i). A wide range of possibilities was accepted from the practicalities of carrying out the experiment, such as a temperature change, through to the approximations or assumptions made in completing the calculation.

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Paper 9701/52

Planning, Analysis and Evaluation

Key Messages

The introduction to a question provides important guidance to help candidates understand the experiment that follows. They should not attempt to answer questions until this information has been absorbed.

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Care is needed to avoid simple errors when writing formulae or carrying out calculations.

General Comments

Question 1 was based partly on practical work examined at AS level. However, many candidates were not confident in these reactions. For this reason candidates found **(a)** and **(b)** particularly demanding.

Question 2 was tackled more successfully and candidates could generally draw the graph and identify the anomaly. Despite the experiment being based on a pH titration procedure, few were able to demonstrate an understanding of the shape of the graph. In **(e)** and **(f)** candidates often tried to apply formulae that were not relevant to the calculation they were attempting. It is worth noting that the Examiners allowed for errors carried forward from one part to the next and on that basis credit was often obtained. A particularly common error in **(d)(i)** was the belief that hydroxide ions were still present in significant quantities once sodium hydroxide had been added to the acid. The misunderstanding appeared to be that because the acid was weak only a small number of hydrogen ions would be neutralised.

Comments on Specific Questions

Question 1

- (a)** Unexpected difficulties were found by those candidates who thought that copper reacted with dilute sulfuric acid or that zinc hydroxide and aluminium hydroxide would be obtained as solutions. Some candidates seemed to have not absorbed the information given in the introduction.
- (b)** Good credit was generally obtained by candidates who had established a clear strategy in **(a)**. However, only a few were able to provide clear reasons for their choices.
- (c)** Many candidates were able to correctly explain that the hydroxides needed heating until constant mass was achieved though some also stated "until no more gas was evolved". Even if steam was identified as the gas this would not be sufficiently reliable.
- (d)** It was surprising that having been guided to obtain the oxides in **(c)** many candidates were unable to provide the correct answer to this question. To obtain a correct mass of copper it should be washed with water (or propanone) and dried. Some candidates suggested electrolysis of the sample which would not be feasible with a precipitate.
- (e)** Many candidates used an incorrect formula for aluminium oxide. Another common error was to forget when calculating the mass that there are two moles of aluminium ions in one mole of aluminium oxide.
- (f)** Few candidates recognised that the small amount of copper in the sample meant that it would be difficult to obtain an accurate mass for it. Many answers mistakenly suggested that the problem

would stem from the high reactivity of copper or the assumption that copper would dissolve in sulfuric acid.

Question 2

- (a) Most candidates plotted the points on the graph reliably although they should be reminded that a point should be indicated using a sharp pencil to allow for precision. It was difficult to draw a curve through the points and the Examiners accepted any that were reasonably close. It had been expected that candidates would be familiar with the experiment and therefore draw a vertical line at the end-point of the reaction but this was not required for credit to be awarded.
- (b) Credit was awarded for the anomalous point(s) based on the curve that had been drawn. Most candidates gained credit but a few did not because they identified a point as being anomalous even though the curve they had drawn went through the point. A correct reason for the anomaly was also given by the majority of candidates, most opting for an explanation based on the suggestion that an incorrect volume of sodium hydroxide had been added.
- (c) A suitable indicator range was correctly identified by many candidates although several wanted to extend the lower range of pH values to 4 or 5 or beyond 11 in the upper range. Some candidates did not read the question carefully and opted to name an indicator rather than a pH range.
- (d)(i) It was clear that candidates did not always understand the process of the titration. A surprising number included the hydroxide ion amongst the ions present in highest concentration. Others did not appreciate that as NaA was generated in the titration, the sodium ion and A^- ion would be present in comparatively large amounts.
- (ii) Candidates struggled to explain how the concentrations of the species in the question compared.
- (e) The vast majority read the graph correctly, gaining credit, but there were instances of incorrect readings. Further credit was available for a statement of K_a either directly or in its logarithmic form. A few candidates went on to gain full credit by recognising that in this mixture at the mid-point of the titration $[HA] = [A^-]$.
- (f)(i) It is important to emphasise to candidates that if they are uncertain of an answer to a previous part they should continue as Examiners will always allow an error carried forward. This was particularly relevant to this question where a significant number of candidates achieved full credit despite an incorrect value for K_a .
- (ii) Some left this part unanswered. Candidates needed to use their answer from (f)(i) and the mass of HA used to calculate a value for the relative molecular mass of the acid.
- (g) By far the most frequently seen answer was that, since HA was weak, it would not fully react with the sodium hydroxide. This represents a misunderstanding which perhaps also accounts for the erroneous answers to 2(d)(i). A wide range of possibilities was accepted from the practicalities of carrying out the experiment, such as a temperature change, through to the approximations or assumptions made in completing the calculation.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key Messages

The introduction to a question provides important guidance to help candidates understand the experiment that follows. They should not attempt to answer questions until this information has been absorbed.

Sufficient practice using class experiments throughout the year is required if convincing answers are to be provided to questions based on the analysis and evaluation of experiments.

Care is needed to avoid simple errors when writing formulae or carrying out calculations.

General Comments

There were two major differences in the presentation of the examination when compared with previous November series. The first was in the planning where questions related to planning were broken down into structured parts. This direction to candidates was to their benefit as it provided an indication to the answer. The second was in the presentation of the graphical question where the axes were provided, labelled with units and scaled. The outcome here was that there was considerably more accuracy in the graphs produced by the candidates which was to their benefit.

There are various points in chemical calculations about which candidates should be aware. Often calculators produce values as vulgar fractions which are acceptable only during the course of a calculation but not as a final answer which needs to be in decimal or standard form to the required significant figures or decimal places. Early or over rounding should be avoided during the course of a calculation, but final answers should be correctly rounded. Mass values should be quoted to the same number of decimal places as the data from which they are derived and with a mass unit. The writing of full equations was reasonably well done but the writing of ionic equations less so. Candidates should be given practice in the writing of ionic equations, especially with less common compound ions, and encouraged to note when the inclusion of state symbols is specified.

Some candidates provided multiple responses to a simple question which sometimes contradicted each other. Candidates should be encouraged to directly respond to each individual question in a straightforward way.

Comments on Specific Questions

Question 1

- (a) Most candidates gave a correct first equation and many also the second. The most common errors were not balancing the aluminium equation or having sulfite and water as products.
- (b) The majority of candidates had a good idea about independent and dependent variables but not all were able to answer correctly. For example, type of metal was sometimes given as independent variable and derived values such as temperature or enthalpy change for dependent.
- (c) (i) Most candidates applied the correct stoichiometry from (a) and calculated a correct acid volume. Some candidates calculated moles correctly but then used a value for molar volume to give an answer as if the acid was a gas. The question specified the answer to be quoted in cm^3 ; some gave an answer in dm^3 .

- (ii) The majority of candidates had a good answer based on the sulfuric acid being in excess, the magnesium needed to react completely or the magnesium was the limiting reagent. Some answers stated "reagent" which was ambiguous.
- (d) Again most candidates gave a good calculation to obtain a correct answer that was acceptable in cm^3 or dm^3 . The majority correctly used the stoichiometric ratio given in (a) even if it was an incorrect ratio. Some incorrectly used a 1:1 ratio which conflicted with their ratio in (a) or again used a molar volume value as if the acid was a gas.
- (e) (i) This question specifically asked for a list of the measurements to be made. The measurements required were volume of acid and initial and final temperatures. Many candidates did not provide all three, usually omitting the acid volume. A common misconception with measurements is the inclusion of quantities that cannot be directly measured such as temperature change or enthalpy change.
- (ii) A significant number of candidates chose some way of reducing heat loss by way of insulation which is the major change that would increase the accuracy of the experiment. Some others proposed stirring which would also be effective. A number of candidates suggested using more accurate apparatus which would have only a minor effect. Suggestions referring to repeating the experiment are more to do with reliability than accuracy.
- (iii) This was a two stage calculation. The first step was to calculate the energy released by the reaction by stating $q = mc\Delta t$. Many gave this but referred to q as energy or enthalpy change or referred to m as the mass of magnesium.

In the second step, the energy value needed to be divided by the moles of magnesium to give the enthalpy change of reaction. Often this division was present but the moles (n) were not defined or sometimes given as moles of acid.

- (f) Very few candidates gained full credit here. The first marking point was available for a correct ionic equation for the reaction between magnesium and aqueous aluminium atoms. Some candidates incorrectly gave Mg:Al as 1:1.

Candidates then needed to understand the data and relate it to the ratios in the ionic equation. The question states that the data of ΔH_1 and ΔH_2 refer to the reactions between magnesium and aluminium respectively as given in (a), so apply to 1 mole of magnesium and 2 moles of aluminium. Thus the enthalpy change for the reaction, ΔH_r , could be calculated as $3\Delta H_1 - \Delta H_2$ assuming that the full and ionic equations given were correct. In this situation errors in any equation were carried forward but even so the majority of candidates did not gain credit here.

The third marking point was available for ΔH_r divided by the moles of magnesium as in the ionic equation, usually 3.

Question 2

- (a) (i) Very few candidates produced a correct ionic equation complete with state symbols. Common answers included full equations, incorrect ions, the presence of non-reacting ions, missing states or no balancing. As the potassium iodate was added to the reaction as a solid, it was easy to see why many had $\text{IO}_3^-(\text{s})$, but the reaction here would be between ions in solution. Some candidates gave the reverse reaction starting with nickel(II) iodate.
- (ii) The calculation here followed on from the stoichiometric ratio given in the equation in (i). A number of candidates perhaps missed "in this experiment" in the question and gave 2 moles as their answer.
- (iii) A significant number of candidates gave no increase, probably not realising that addition of more iodate would pull nickel(II) iodate out of solution, according to the common ion effect, as the solubility product remains constant. Some candidates who had a correct increase cited the common ion effect as a reason, although an explanation was not required. Unfortunately a correct effect was often negated by a contradicting explanation e.g. equilibrium shifts.

- (b) (i) The provision of a labelled and scaled grid gave the candidates the opportunity to show good point and line plotting. The majority of candidates plotted the data points well. All the points should have been plotted on a vertical grid line and this was usually the case. However, points that should not be on a horizontal grid line sometimes were plotted there. For example, the point at $y = 11.97\text{ g}$ was wrongly plotted on a grid line of $y = 12\text{ g}$ rather than just below that line. While most candidates drew a good line with their points (ignoring the obvious anomalies), a significant minority did not realise that 0,0 was a valid point and did not include it in their line. A few did not complete the line to the origin or just missed it.
- (ii) If the points and line were correctly plotted there were two obvious anomalies and most candidates successfully identified them. In the case of mis-plots, more or fewer anomalies could be identified and were treated accordingly. A few candidates did not label any anomalies.
- (iii) The part of the procedure that introduces experimental error was procedural difficulties associated with filtering, such as not transferring all of the precipitate or insufficient drying. This question produced many list answers where successive responses often contradicted or negated each other.
- (iv) The first point at 0.1000 mol required an extrapolation of the line to 0.1000 and marking a point where that grid line intersects the line. The second point had to be on the 0.1200 mol grid line at least at the level of the first point and still in the given grid. A number of candidates did not extrapolate so could not plot the first point and many candidates extended the 0.1200 grid line out of the given grid to make the second point out of the grid by extending the extrapolated line. A number of candidates misread 0.1000 as 0.01000 and incorrectly plotted points at the bottom left of the grid.

(c) This question was a series of follow on calculations which are often successfully solved by retaining calculator value and carrying it on to the next part.

- (i) This was a fairly straightforward calculation using the stoichiometric ratio of nickel(II) to iodate as given in (a)(i) and using the data of 0.0400 moles iodate from experiment 3. A few candidates used data from experiment 1. Others wrongly based the calculation on the initial concentration of nickel(II) sulfate or involved the 7.92 g of precipitate. Some calculations were extremely complex and unnecessary but incorrect answers were carried forward through this question. As the mass data was presented to two decimal places then that was required as a minimum for the final answer.
- (ii) Most candidates succeeded with this subtraction although a few did not quote to a minimum of two decimal places or neglected the unit.

Again, most candidates correctly applied the formula mass to the first answer to moles in solution.

This part was a straightforward doubling of the previous answer which many candidates did not realise. Most errors involved subtracting the above answer from a variety of quantities, notably 0.02.

- (iii) Most candidates correctly took the final answer from (ii) into this calculation. The major error was using that result and 0.0306 directly into the solubility product expression. These values were of moles in 100 cm^3 so needed to be multiplied by 10 to give a concentration in mol dm^{-3} which was required for substitution into the solubility product expression. The majority of candidates calculated their data correctly, though a small number missed the square term. Some candidates incorrectly multiplied the final answer from (ii) by 2 as well as squaring it.