CHEMISTRY

Paper 9701/11

Multiple Choice

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

General Comments

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

Twenty one questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 1**, **3**, **4**, **5**, **6**, **8**, **9**, **10**, **12**, **14**, **17**, **18**, **22**, **24**, **27**, **29**, **30**, **31**, **34**, **37** and **39**. Since **Questions 37** and **39** are on this list it can be suggested that most candidates found they had sufficient time to complete the paper.

Six questions can be said to have been found to be particularly difficult. Less than 35% of candidates chose the correct responses to each of **Questions 11**, **21**, **25**, **28**, **32**, **and 35**.

Comments on Specific Questions

Question 11

26% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 54% of candidates. The amount of $SnCl_2$ in the question is 0.05 moles. Because of the stoichiometry of the reaction (worked out using oxidation states) this will produce 0.02 moles of Mn^{2+}. Candidates choosing **C** may have ignored the stoichiometry, assuming 0.05 moles of $SnCl_2$ will produce 0.05 moles of Mn^{2+}.

Question 21

33% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 31% of candidates. **B** is correct because the secondary alcohol group in lactic acid will form an ester with methanoic acid. **C** is incorrect because the secondary alcohol group in lactic acid is not acidic enough to liberate CO_2 from $NaHCO_3$. It is possible that some candidates did not select **B** because the given formula of the organic product, $CH_3CH(O_2CH)CO_2H$, proved difficult to comprehend. In this situation candidates may make the question easier for themselves by drawing out fully displayed formulae on their question paper.

Question 25

26% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 31% of candidates. The compound described in option **C** would have **two** chiral centres, so this is not the answer. Again, drawing out fully displayed formulae would have helped those candidates who found imagining the molecules difficult.

Question 28

33% of candidates chose the correct answer, **D**. The remaining options were each selected an approximately equal number of times. Questions involving the naming of esters are normally answered well, so it is likely that the effect of hydrogen bonding of esters on their boiling points was where candidates found difficulty.

Question 32

33% of candidates chose the correct answer, **B**. Options **A** and **C** were both selected by 30% of candidates. Most candidates were therefore confident that statement 2 is correct. The key statement is statement 3. Having a higher first ionisation energy would make an atom less able to contribute to the 'sea of delocalised electrons' causing a **decrease** in melting point.

Question 35

32% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 30% of candidates. X, Y and Z should have been identified as calcium compounds; Z is therefore $Ca(OH)_2$. When $Ca(OH)_2$ is added to soil it neutralises acid, so the pH of the soil is increased, not decreased, so statement 3 is incorrect.

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

General Comments

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

Nineteen questions can be said to have been found to be easier. 60% or more of candidates chose the correct responses to each of **Questions 2**, **3**, **4**, **6**, **7**, **8**, **15**, **16**, **17**, **18**, **20**, **24**, **28**, **29**, **33**, **35**, **36**, **37** and **38**. Since **Questions 37** and **38** are on this list it can be suggested that most candidates found they had sufficient time to complete the paper.

Five questions can be said to have been found to be particularly difficult. 45% or less of candidates chose the correct responses to each of **Questions 10**, **14**, **25**, **31**, and **40**.

Comments on Specific Questions

Question 10

45% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answers were **B** and **C**, with 22% of candidates choosing **B** and 18% choosing **C**. Candidates who chose **B** had probably worked out the energy change $25 \times 4.18 \times 2.5$ rather than $50 \times 4.18 \times 2.5$. Candidates who chose **C** may not have appreciated the significance of joules and kilojoules as units, or may not have converted the volumes from cm^3 to dm^3.

Question 14

42% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answers were **B** and **C** with 25% of candidates choosing **B** and 22% choosing **C**. This suggests that a significant number of candidates knew one of the two trends (of solubility of group II hydroxides and stability of group II carbonates) but not both.

Question 25

37% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. It is possible to suggest two reasons for choosing **B**. Firstly, candidates may have erroneously believed that concentrated sulfuric acid would behave only as an oxidising agent in this reaction. Secondly, candidates who did not know how concentrated sulfuric acid would behave in this reaction may have chosen **B** because the structure shows an oxygen atom in the same position as in menthol.

Question 31

28% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 41% of candidates. For many candidates this question therefore rested on the truth, or otherwise, of statement 3. Statement 3 is true, the key word in the question being **unpaired**. A carbon atom has two p electrons, therefore it has two unpaired p electrons. A Cl^+ ion has four p electrons, therefore it has two paired and two unpaired p electrons.

Question 40

25% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 56% of candidates. It is possible that many candidates saw C_4 in the question and then chose statements 2 and 3 because these statements each had a compound with four carbon atoms per molecule, either butanedioic acid or methylpropanedioic acid. However, if either of these compounds is reacted with calcium metal it can produce a salt with empirical formula $CaC_4H_4O_4$, but not $CaC_4H_6O_4$. However ethanoic acid, CH_3CO_2H, reacts with calcium metal to produce calcium ethanoate, $Ca(CH_3CO_2)_2$, which does have empirical formula $CaC_4H_6O_4$.

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

General Comments

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

Nineteen questions can be said to have been found to be easier. 65% or more of candidates chose the correct responses to each of **Questions 1**, **2**, **3**, **4**, **5**, **6**, **9**, **11**, **13**, **15**, **16**, **17**, **18**, **19**, **21**, **28**, **30**, **33** and **38**. Since there are few questions from the end of the paper on this list it is possible that some candidates encountered time pressure during the examination.

Five questions can be said to have been found to be particularly difficult. 40% or less of candidates chose the correct responses to each of **Questions 12**, **26**, **29**, **35**, and **40**.

Comments on Specific Questions

Question 12

34% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 34% of candidates. Candidates needed to know the correct decomposition reaction;

$$Mg(NO_3)_2 \rightarrow MgO + 2NO_2 + \frac{1}{2}O_2$$

giving a ratio of 92/16 which is 1/0.174.

Question 26

36% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answers were **B** and **C** with 23% of candidates choosing **B**, and 27% choosing **C**. Candidates that chose **B** did not appreciate that 2-methylbutan-2-ol, a tertiary alcohol, cannot be oxidised by acidified potassium dichromate(VI). Those that chose **C** did not appreciate that pentan-1-ol is oxidised to propanoic acid which has stronger hydrogen bonding and therefore a higher boiling point. Pentan-2-ol will be oxidised to pentan-2-one, which has no hydrogen bonding and therefore has a lower boiling point than pentan-2-ol, so the answer is **D**.

Question 29

23% of candidates chose the correct answer, **D**. 20% of candidates chose **A**, 25% chose **B**, and 32% chose **C**, suggesting that many candidates guessed. Candidates would have benefitted from drawing out fully displayed formulae on their question paper to help them answer this question.

Question 35

39% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 26% of candidates. The important phrase here was "When Y is hydrated, it forms compound Z which is used agriculturally to treat soils". It was hoped that candidates would recognise CaO and $Ca(OH)_2$ from this information.

Question 40

37% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 46% of candidates. For many candidates this question therefore rested on the truth, or otherwise, of statement 1. Statement 1 states that ethanoic acid can be made by the hydrolysis of ethanenitrile, which is correct. It is possible that some candidates, on reading ethanenitrile, imagined that this is CH_3CH_2CN, which gives propanoic acid when it is hydrolysed.

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Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. Candidates would have benefitted from this particularly in **Question 1(a)** where there were unbalanced equations, **Question 2(c)** where there was often no sign in the final answer and in **Questions 3(a)** and **4** where names were used, rather than symbols/formulae.

Candidates need to ensure that they are confident about the differences between structural, displayed and skeletal formulae as asked in **Questions 5(a)**, **(b)** and **(c).** Information about these different formulae is given in *section 10.1* of the syllabus.

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 a sound knowledge of organic chemistry shown by many candidates.

Comments on Specific Questions

Question 1

This question was generally well answered, with many candidates achieving full credit. Candidates should be careful not to round off their answers too early or give an incorrect number of significant figures.

(a) **(i)** Almost all candidates gave a correct first equation but there were examples of unbalanced equations or wrong products for the second reaction.

(ii) The majority of candidates gave the correct answer. A small number incorrectly rounded up this answer to 0.08.

(iii) This part was generally well answered.

(iv) The majority of candidates gave the correct answer.

(v) Many candidates gave the correct answer.

(vi) While this part was generally well answered, some candidates used an incorrect value of relative molecular mass for $(NH_4)_2SO_4$.

(vii) Many candidates gave the correct answer. However, a number did not read the question carefully and did not give their final answer to the correct number of significant figures – three in this case. *Section 1(h)* of the syllabus contains important information about significant figures.

A small number of candidates completed this calculation even though their mass of $(NH_4)_2SO_4$ was greater than the initial sample mass of 2.96 g. There was little evidence of any of these candidates attempting to find the error and correct their answer.

(b) There were many good responses to this part although some candidates incorrectly believed that the process of photosynthesis uses up oxygen.

(c) This was quite well answered. Popular incorrect answers included the use of ammonia in making soaps and detergents or as bleach.

Question 2

The ability to apply both Le Chatelier's Principle and Hess' Law correctly is important to success in AS level chemistry. There were many good answers to **(a)** and **(b)** but **(c)** was less well answered with a significant number of candidates struggling with the calculation.

(a) Many candidates confused K_c and K_p offering a K_p expression involving square brackets which represent concentration in mol dm^{-3}. Those candidates who gave a correct expression for K_p in terms of partial pressures usually gave correct units for K_p.

(b) Both parts of this question were generally well answered with good explanations in terms of Le Chatelier's Principle.

(c) While there were many fully correct answers in this part, there was a significant number of candidates who were awarded very little credit. The most common error was to not give a sign in the answer as the question required. Some candidates did not use the 4 and/or 6 from the stoichiometry of the equation in their algebraic equation.

Question 3

The concept of periodicity lies at the heart of inorganic chemistry in the A level chemistry syllabus. Those candidates who had studied periodicity carefully answered this question well. However, there were many answers that revealed a lack of knowledge and understanding of the relevant material.

(a) Many candidates gave quite good answers to this part. A small number incorrectly gave names rather than symbols of the elements as required.

    (i) The majority of candidates gave a Group I element as their answer. The most common incorrect answer was Mg.

    (ii) This was generally well answered although a metal was a popular incorrect response.

    (iii) This part was correctly answered by most candidates with Li as the most common incorrect response.

    (iv) While many candidates answered this part correctly, Si was a common incorrect answer.

    (v) There were many correct answers to this part.

    (vi) This was less well answered with many candidates incorrectly suggesting Na or Mg.

(b) This part saw many good answers. A small number of candidates gave the formulae of elements or compounds that were not oxides.

    (i) A very common incorrect answer to this part was MgO.

    (ii) There were many correct answers to this part.

    (iii) In this part, some candidates gave oxides of silicon while others gave the same oxide of phosphorus such as P_2O_5 and P_4O_{10}.

    (iv) This was correctly answered by most candidates.

(c)

    (i) Most candidates gained some credit in this part. Common mistakes were to show eight rather than ten electrons around the Cl atom or to not include all of the lone pairs around the F atoms.

    (ii) This part was less well answered with many candidates struggling to explain clearly the difference in boiling points. Examiners were looking for a straightforward explanation, either in terms of van der Waals' forces and numbers of electrons present in each molecule or in terms of permanent dipoles and the differences in electronegativity between Cl and F on the one hand and Br and F on the other. In each case, candidates were expected to explain how the property to which they referred caused the effect.

    Many candidates gave confused arguments which referred to the covalent bonds within the ClF_3 or BrF_3 molecules rather than concentrating on the forces between the molecules.

    Some candidates thought that only one of the molecules contained a permanent dipole and only one compound had van der Waals' forces. In fact, both have both.

Question 4

Questions on organic chemistry largely test a candidate's ability to recall the relevant material; some responses here showed a lack of knowledge or a lack of care with the answer.

Candidates were asked to extract the names of types of reaction from two lists given. While many did this successfully, there was a significant number who did not use both lists to give a full description of the reaction type. A small number used terms that were not given in the question and were not awarded credit for this.

The question asked for the formulae of the reagents used, so candidates who gave names were not awarded credit. In the second reaction Br_2 was the required answer; Examiners did not accept Br or $Br_2(aq)$. In the fourth reaction, credit was only given if a candidate stated clearly that H_2SO_4 was concentrated.

Question 5

This question tested candidates' ability to apply their knowledge and understanding of alkene and aldehyde functional groups. While some candidates coped very well with the question, many struggled to decide which of the two functional groups in crotonaldehyde would react with each reagent.

(a) Reactions A and B were well known by most candidates. In reaction C, a large number of candidates did not realise that the aldehyde group in crotonaldehyde would also be reduced. For reaction D, many candidates thought that $NaBH_4$ would react with the alkene group as well as with the aldehyde group. The product in reaction E was correctly described by most candidates.

(b) This question specifically asked for the displayed formulae of the two isomers of crotonaldehyde. However, many candidates gave structures involving $-CH_3$ and $-CHO$ which were not fully displayed and so could not be awarded credit.

(c) Candidates continue to struggle with skeletal formulae. Many candidates included a hydrogen atom on the aldehyde group or incorrectly showed carbon atoms.

(d) This part was less well done by many candidates.

    (i) Only the more able candidates deduced that a diol was formed under the conditions quoted.

    (ii) Fewer candidates were able to give the two compounds, ethanoic acid and ethanedioic acid, that will be formed by rupture of the $>C=C<$ bond with a solution containing hot concentrated acidified manganate(VII) ions.

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Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. Candidates would have benefitted from this particularly in **Questions 3(a)** and **3(b)** where names were used rather than the required symbols/formulae and in **Question 5(b)** where structures that were not esters were given.

Candidates need to ensure that they are confident about the differences between structural, displayed and skeletal formulae as asked in **Questions 4(a)**, **(b)**, **(c)** and **5(b)**. Information about these different formulae is given in *section 10.1* of the syllabus.

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 a sound knowledge of organic chemistry shown by many candidates.

Comments on Specific Questions

Question 1

In this question, candidates were asked to use their knowledge and understanding of different aspects of the chemistry of ammonia and sulfuric acid. Examiners saw many confused answers to parts of this question.

(a) Many candidates found this part difficult. Examiners expected a statement such as 'a base is a proton acceptor' coupled with an explanation of what a weak base is. While many candidates stated that a weak base is partially ionised, a significant number incorrectly described it as being 'partially soluble'.

The question asked for an equation and many of these did not include an equilibrium sign.

(b)
   (i) The operating conditions for the Contact process were well known by many candidates. Common mistakes were to use much too high a pressure or to not make clear the oxidation state of the vanadium oxide used.

   (ii) Many candidates knew that sulfur trioxide is not simply dissolved in water to make sulfuric acid. However, a significant number of candidates dissolved SO_3 in concentrated H_2SO_4 and then incorrectly assumed that the 2% water in this sulfuric acid was sufficient to make the new batch of concentrated H_2SO_4.

(c)
   (i) This part was generally well answered with many well drawn and correct structural formulae.

   (ii) This was less well answered. Examiners expected the answer 'nucleophilic substitution' and often the first word was missing.

Question 2

This question was generally well answered, with many candidates achieving full credit. Candidates should be careful not to round off their answers too early or give an incorrect number of significant figures.

(a)

    (i)   Almost all candidates gave a correct answer to the first calculation. A small number incorrectly rounded up this answer to 0.03.

    (ii)   The majority of candidates gave the correct answer.

    (iii)   This part was generally well answered.

    (iv)   Fewer candidates gave the correct answer here.

    (v)   Most candidates correctly used the stoichiometry of the second equation that was given in the question.

    (vi)   This part caused problems for many candidates who were unable to deduce from the first equation that was given in the question that one mole of $NaNO_3$ produces one mole of NH_3 when reacted with Devarda's alloy.

    (vii)   Many candidates gave the correct answer. A small number used an incorrect relative molecular mass of $NaNO_3$.

    (viii)   Many candidates correctly calculated the final answer. However, a number did not read the question carefully and did not give their final answer to the correct number of significant figures – three in this case. **Section 1(h)** of the syllabus contains important information about significant figures.

            A small number of candidates completed this calculation even though their mass of $NaNO_3$ was greater than the initial sample mass of 1.64 g. There was little evidence of any of these candidates attempting to find the error and correct their answer.

(b)   Most candidates correctly stated the oxidation number of nitrogen in $NaNO_3$. Fewer did so for NH_3 with the most common incorrect answer being +3.

Question 3

The concept of periodicity lies at the heart of inorganic chemistry in the A Level chemistry syllabus. Those candidates who had studied periodicity carefully answered this question well. However, there were many answers that revealed a lack of knowledge and understanding of the relevant material.

(a)   Many candidates gave quite good answers to this part. A small number incorrectly gave names rather than symbols of the elements as required.

    (i)   Many candidates correctly gave Ca as their answer. The most common incorrect answers were Mg or a Group I metal.

    (ii)   This was generally well answered although C*l* was a popular incorrect response.

    (iii)   This part was correctly answered by most candidates.

    (iv)   While many candidates answered this part correctly, C was a common incorrect answer.

    (v)   There were many correct answers to this part although Na and Mg were popular incorrect responses.

    (vi)   This was less well answered with many candidates incorrectly suggesting Na or Mg.

(b) This part was generally well answered though a small number of candidates chose elements that were not from Period 3.

  (i) Most candidates sensibly chose familiar elements such as Na or Mg. However, flame colours were often incorrect, suggesting that candidates had possibly not carried out such reactions or seen them demonstrated.

  (ii) There were many correct answers given to this part although some candidates were unsure of the pH of the solution of the chloride they had chosen.

(c)

  (i) This was correctly answered by the majority of candidates.

  (ii) While there were some good answers to this part, many candidates struggled to explain clearly the difference in boiling points. Examiners were looking for a straightforward explanation in terms of increasing intermolecular forces from Cl_2 to ICl. Acceptable answers involved induced dipoles increasing in strength because of the increase in the numbers of electrons in the relevant molecules, or the increasingly strong permanent dipole in the two compounds.

  Many candidates gave confused arguments which referred to the covalent bonds within the three molecules rather than concentrating on the forces between the molecules.

  (iii) Most candidates stated that ICl would have the largest permanent dipole but many of them did not explain clearly, in terms of the relative electronegativity of the elements concerned, why this would be the case.

Question 4

Questions on organic chemistry largely test a candidate's ability to recall the relevant material; some responses here showed a lack of knowledge or a lack of care with the answer.

(a) Many candidates confident in organic chemistry gave good answers here. Some candidates drew displayed formulae so that they could check their structures and Examiners welcomed this. There were, however, many careless answers with hydrogen atoms missing from structures or extra carbon atoms included.

  Reactions D and E produced the most incorrect answers. In D, many candidates believed that $NaBH_4$ will add hydrogen atoms across a $>C=C<$ bond. Common incorrect answers to E were either the formation of $CH_3CH=CHCHO$ or the rupture of the $>C=C<$ bond to produce both CH_3CO_2H and $(CO_2H)_2$.

(b) This part was generally well answered although some candidates did not show clearly how a –OH group is attached to the relevant carbon atom or did not display the methyl group.

(c) Candidates continue to struggle with skeletal formulae. Many candidates were unable to represent the carboxylic acid group correctly, often including the carbon atom of that group in their structure. A small number of candidates incorrectly showed carbon atoms throughout their structures.

(d)

  (i) This part was well answered by many candidates who chose a suitable reagent and correctly described what would be observed.

  (ii) Fewer candidates understood that the conversion of crotonaldehyde into crotyl alcohol is an example of reduction.

(e) Many candidates answered this part correctly. A very small number used proton numbers rather than values of A_r in their calculation but the most common error was in rounding off the numerical answers to the first step of the calculation.

Question 5

This question tested candidates' ability to apply their knowledge and understanding of isomerism and the reactions of aldehyde and ketone functional groups. While some candidates coped very well with the question, many struggled to draw four isomers which were esters with the molecular formula $C_4H_8O_2$.

(a) Most candidates correctly stated the molecular formula of **Q** to be $C_4H_8O_2$.

(b) This was very well answered by those who drew clear structural or displayed formulae. However, there was a significant number of candidates who could only produce two or three correct structures. For many of these candidates, their remaining structures were acids or alcohols rather than esters.

(c)

    (i) This was correctly answered by many candidates.

    (ii) This too was generally well answered.

    (iii) Fewer candidates correctly identified the functional group present in **R** as carboxylic acid.

(d)

    (i) While many candidates correctly answered this part, there were also many answers which did not identify compound **R** as ethanoic acid. Examiners did not accept answers such as 'acid' or 'carboxylic acid'.

    (ii) Many candidates struggled with this part.

(e) Many, but by no means all, candidates correctly stated that none of the esters with the molecular formula $C_4H_8O_2$ would be chiral.

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Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. Candidates would have benefitted from this particularly in **Questions 1(b)** and **(d)** where there were unbalanced equations, **Question 1(c)** where there was often no sign in the final answer and in **Questions 3(a)** and **(b)** where names were used, rather than symbols/formulae.

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 a reasonable knowledge of organic chemistry shown by many candidates.

Comments on Specific Questions

Question 1

The ability to apply Hess' Law correctly is an important skill in AS level chemistry. There were many good answers to this question although a significant number of candidates struggled with the calculation.

(a)

    (i) The majority of candidates gave a correct answer. The most common error was to give the incorrect number of outer electrons for sulfur. This was usually, but not always, associated with a similar error for the number of outer electrons for carbon.

    (ii) This was generally well answered although a small number of candidates incorrectly thought that a linear shape involved a bond angle of 120°.

(b)

    (i) This was correctly answered by the majority of candidates.

    (ii) Fewer candidates gave a fully correct definition for the standard enthalpy change of combustion of CS_2. A significant number did not refer to one mole of CS_2 or state that the reaction must be carried out with an excess of oxygen or air. A small number referred to '... the energy required to... ' and were given no credit because combustion is always an exothermic reaction. Examiners expected candidates to begin their answers with a term such 'It is the enthalpy change when ...'.

(c) Many candidates were able to carry out this calculation correctly although some, whose calculation was correct, could not be awarded full credit as their answer did not include a sign as the question required. A significant number of incorrect answers involved arithmetic errors. A very small number of candidates attempted to answer this question in terms of S_8 rather than S. These candidates did not understand that $\Delta H_f^{\ominus}$ for SO_2 refers to the formation of 1 mol of SO_2 from 1 mol of S atoms and unnecessarily divided the value of $\Delta H_f^{\ominus}$ for SO_2 by 8.

(d)

(i) This was quite well answered with many candidates correctly deducing the identities of the products,

(ii) Fewer candidates were able to give two correct oxidation states in this part.

Question 2

An understanding of and ability to apply Le Chatelier's Principle are important to success in AS level chemistry. There were many good answers to **(a)** but **(b)** was less well answered with a significant number of candidates struggling with the calculation.

(a)

(i) There were many good answers to this part. However, some responses did not make it clear that Le Chatelier's Principle applies to a chemical equilibrium.

(ii) The majority of candidates applied Le Chatelier's Principle correctly to the given equilibrium. Some candidates explained the effects of the changes they proposed on the rate of the reaction rather than on the yield of methanol.

(b) There was a good number of correct answers to this calculation although some were obtained by using the solution of a quadratic equation which was unnecessary. The syllabus, in ***section 7(f)***, makes it clear that such a method is not required. Reasons for not obtaining full credit were incorrectly deducing the equilibrium concentrations, incorrect expressions for K_c or arithmetical errors.

Question 3

The concept of periodicity lies at the heart of inorganic chemistry in the A Level chemistry syllabus. Those candidates who had studied periodicity carefully answered this question well. However, there were many answers that revealed a lack of knowledge and understanding of the relevant material.

(a) Many candidates gave quite good answers to this part. A small number gave names rather than formulae of the elements as required.

(i) The majority of candidates correctly gave a noble gas as their answer. The most common incorrect answer was H.

(ii) This was generally well answered although C was a popular incorrect response.

(iii) Although there are only two elements that are liquid at room temperature, a significant number of candidates did not give Br as their answer.

(iv) This was generally well answered.

(v) While Si was a popular and correct response, Al was often given in its place.

(vi) This was less well answered with many candidates not knowing that phosphorus can form the P^{3-} anion.

(vii) Candidates struggled to give the correct answer to this question, many giving an element that will react with water – such as Na – rather than one that will then form a solution that can behave as an oxidising agent.

(b) Answers to this part were generally sound although some candidates made careless mistakes in their formulae.

(i) This was generally well answered although SiO_2 was a frequent incorrect answer.

(ii) While many candidates answered this part correctly, a significant number gave MgO as their response although it has a slow reaction with water.

(iii) There were many incorrect answers to this part with $MgSO_4$ being a common incorrect response.

(c) This part was less well answered with many candidates struggling in **(ii)**.

(i) Many candidates knew that SiO_2 has a giant molecular structure which gives rise to its high melting point. However, some candidates described the process of melting as breaking intermolecular bonds rather than the strong covalent bonds within the SiO_2 macromolecule.

(ii) This part was poorly answered by many candidates, a significant number of whom did not know how to interpret the data. Although the majority understood that all three elements had simple molecular structures, many of these candidates were unable then to explain the difference in melting points in terms of van der Waals' forces. Too often the molecular formulae of the three elements – and hence the numbers of electrons in each molecule – were not given. As a result, any explanation in terms of van der Waals' forces was incomplete.

One common misunderstanding among some candidates was that when melting simple molecular elements the covalent bonds within the molecules rather than the weak intermolecular forces between them are broken.

Question 4

Questions on organic chemistry largely test a candidate's ability to recall the relevant material and many candidates were able to do this. However, many answers involved incorrect organic chemistry.

(a)

(i) Many candidates confident in organic chemistry gave good answers here. Some candidates drew displayed formulae so that they could check their structures and Examiners welcomed this. There were, however, many careless answers with hydrogen atoms missing from structures or extra carbon atoms included.

(ii) This was often poorly answered with many incorrect reagents being quoted.

(b) Answers here were generally of a poor quality, with a significant number of candidates not being secure in their knowledge of these reactions. In the case of the one reaction that does occur – that with HCN – many products were incorrect because they did not include either a nitrile group or a hydroxyl group.

(c) Here a significant number of candidates did not read the question and incorrectly offered litmus as the reagent.

Question 5

This question tested candidates' ability to apply their knowledge and understanding of organic reactions in an unusual context. While some candidates coped very well with the question, many struggled to decide which of the two functional groups in allyl alcohol would react with each reagent.

(a)

(i) This was quite well answered although some candidates drew structural formulae with missing hydrogen atoms.

(ii) This was less well answered with many candidates incorrectly believing that Br_2 would react with the –OH group in allyl alcohol.

(iii) Similarly, many candidates incorrectly thought that cold, dilute, acidified potassium manganate(VII) would react with both functional groups in the alcohol.

(iv) While many candidates correctly gave ethanedioic acid as the product of the reaction, a significant number thought that methanoic aid or methanal would also be formed.

(b)

(i) Many candidates correctly identified this reaction as an example of nucleophilic substitution. Those candidates who simply gave 'substitution' as their answer were not awarded credit.

(ii) This was well answered by many candidates.

(c)

(i) Fewer candidates answered this part correctly. Some incorrectly described heating the reagents under reflux which would produce propanoic acid.

(ii) This was generally well answered.

(d) Only a minority of candidates recognised that in this reaction the use of the ruthenium(IV) catalyst enables the reduction of the alkene group and the oxidation of the alcohol group in a single step reaction.

CHEMISTRY

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.
- 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 lines of best fit should have balanced points either side of the line with anomalies/outliers ringed or labelled as such.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places.
- Instructions in the rubric need to be read and acted upon.

General Comments

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

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

Comments on Specific Questions

Question 1

The majority of the candidates successfully completed the practical work and were able to gain credit for drawing the graph and the calculation.

(a) Almost all candidates recorded all the required thermometer and volume readings; 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, all readings should be recorded to the nearest 0.5 °C. The majority of candidates gave suitable headings to their tables and displayed the units of temperature and volume correctly. Only a few candidates were unable to gain any credit for accuracy.

(b) The vast majority of candidates completed the table correctly.

(c) Almost all candidates labelled the axes correctly though a number chose scales that did not occupy more than 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. Credit for the line of best fit was awarded to many candidates though a significant number appeared to try to make the maximum correspond to the highest value they had obtained from the table in **(b)** whilst others did not have balanced points on both sides of the lines. Most candidates correctly read the volume of **FA 2** at the intersection of the lines.

(d) A majority of candidates were able to calculate the number of moles of sodium hydroxide in 25.0 cm^3 of **FA 1** (0.0500), to realise that half this number of moles of sulfuric acid were needed and to calculate the concentration of **FA 2**. A number of candidates, however, gave answers correct to only one significant figure and so were penalised.

(e) There were several possible acceptable answers here but they needed to be precise. Please refer to the published mark scheme for examples.

Question 2

(a) A surprising number of candidates omitted the burette readings for the rough titration even though the instruction to do so was clear and space was available. There was a large number of candidates (and some Supervisors) who did not record burette readings to .x0 or .x5 cm^3. Since the burette is calibrated at .1 cm^3, all readings should be recorded to the nearest 0.05 cm^3. A majority obtained concordant titres and were able to gain at least partial credit for accuracy. Some candidates showed that the dilution and titration had been carried out with suitable care. However, some candidates produced a large range of titres with few in agreement.

(b) The majority of candidates were able to obtain a suitable value from their data to use in the calculation. Those that did not obtain credit here did not show working, incorrectly used the value from a rough titre, included results with too great a spread, incorrectly rounded for the final answer or gave the final answer to too few decimal places.

(c) As in **Question 1** most candidates coped well with the principles involved in the calculation. In this case however many did not gain full credit as they did not take into account that **FA 2** had been diluted by a factor of 10 to produce **FA 4**.

(d) A number of candidates gained credit here but others, particularly those who had obtained answers that were incorrect by a factor of 10 in **(c)**, appeared not to believe the answer that resulted. Candidates should be advised that credit can be gained using incorrect data from a previous section, if the correct method is applied.

Question 3

Although many candidates gave good answers here, some ignored the instruction to give the full name or formula of any reagent selected for a test. Use of the Qualitative Analysis Notes helps with the descriptions of precipitates formed.

(a) Most candidates were awarded at least half of the credit available in this section. The most common omissions were the starting colour for the solution when **FA 7** and **FA 6** were used and the identification of the gas formed from **FA 8** and **FA 5**.

(b) Most candidates used their observations from **(a)** to correctly deduce the ions present in the solutions. A few candidates incorrectly deduced that one of the ions could be present in more than one solution.

(c) This part was only answered correctly by the most able candidates. The presence of H$^+$ could be deduced from the change in colour of chromate(VI) or the evolution of a gas from carbonate ions.

(d) As in **(c)**, only the most able gained credit in **(i)** where it was necessary to recognise that white lead bromide would be formed instead of white lead chloride and hence that there would be no difference in observation.

Many more candidates however gained credit in **(ii)** with most recognising the need to include both aqueous silver nitrate and aqueous ammonia in the description of the test.

CHEMISTRY

| Paper 9701/32 |
| 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.
- 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 lines of best fit should have balanced points either side of the line with anomalies/outliers ringed or labelled as such.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places.
- 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:

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- 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. Regrettably a number of Centres do not provide, or provide incomplete, Supervisor information. Also, Invigilators/Supervisors at Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

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

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

Comments on Specific Questions

Question 1

The majority of the candidates completed the practical work, drew clear, correctly labelled tables, and were able to gain credit for drawing the graph and the calculation.

(a) Most candidates completed the table, gave two balance readings and correctly calculated the mass of **FB 1** used. Headings were generally shown in an appropriate manner but candidates should be reminded to record all thermometer readings to .0 °C or .5 °C as the calibration is at 1 °C. Most candidates gained at least partial credit for the accuracy with which they carried out the procedure

(b) Almost all candidates labelled the axes correctly though a number chose scales that did not include the 1°C below the minimum temperature reached, as instructed. The plotting was generally good though some candidates used large, often imprecisely placed, blobs to denote the points. Credit for the lines of best fit was awarded to many candidates although some ignored points off the lines or did not have balanced points about the line. A significant number of candidates did not extrapolate the lines to determine the temperature change at 2½ minutes.

(c) Candidates should be encouraged to read through practical instructions completely before starting work. A significant number of candidates started recording thermometer readings every minute as in **(a)** – this was unnecessary and costly in terms of time. However, many candidates gained full credit for a suitable table and good levels of accuracy.

(d) While most candidates calculated the heat energy changes in **(i)** and **(iii)** correctly, some used the mass of solid, instead of the volume of solution, even though the specific heat capacity was given in $J\,cm^{-3}\,{}^{\circ}C^{-1}$. Most candidates correctly calculated the formula masses of **FB 1** and **FB 2** and many answered **(ii)** and **(iv)** in two stages, first calculating the number of moles and then calculating ΔH. This is clearly acceptable but care must be taken not to approximate intermediate answers to too few significant figures. Most candidates converted J to kJ and recorded the correct signs in **(ii)** and **(iv)**. Part **(v)** of the calculation proved more challenging for some, as the Hess' law cycle was often incorrectly drawn / interpreted.

(e) Although the table was drawn in a way to encourage candidates to realise that the error involved in measuring the mass of **FB 2** is twice that which applies to a single balance reading, a significant number of candidates did not realise this. If credit was not awarded in **(i)**, it was possible to gain credit in **(ii)** through error carried forward, although a few candidates did not use their mass of **FB 2** from **step 2**.

(f)

    (i) Many candidates recognised that the student's suggestion was incorrect by stating that the acid was already in excess or that the temperature change would be less.

    (ii) Only the most able candidates gained credit here. Most ignored the instruction given in the question, that some type of calculation comparing the data was needed to see whether the two results were consistent. Merely discussing the general advantages of finding a mean was insufficient.

Question 2

Although many candidates gave good answers here, some ignored the instruction to give the full name or formula of any reagent selected for a test. Use of the Qualitative Analysis Notes helps with the descriptions of precipitates formed.

(a) The majority of candidates gained at least half the credit available here. The most common errors were omitting the aluminium and/or the heat when testing for a nitrate with aqueous sodium hydroxide and not making it clear that it is the gas that is tested with red litmus paper in this test.

(b) Many candidates gained at least partial credit with the marking point most commonly missed being the darkening of the off-white precipitate produced from **FB 4**.

(c) Candidates generally used their observations sensibly (even with slight variations in colour) to identify the ions present. Some however had apparently not noted that, at the beginning of the question, it was stated that the possible anions were sulfate, chloride or nitrate and they then concluded that other anions were present.

(d) Any test for an acid, including the use of an indicator, was acceptable but few candidates were able to suggest more than one possible test. Many suggested a test based on the change in colour of chromate(VI) but the majority of these started incorrectly with dichromate(VI).

CHEMISTRY

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 the nearest $0.05\,cm^3$.
- 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 lines of best fit should have balanced points either side of the line with anomalies/outliers ringed or labelled as such.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places.

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

This paper proved slightly more challenging than others taken in the session although a wide range of credit was awarded. Weaker candidates encountered time problems and a significant minority did not complete the paper.

Comments on Specific Questions

Question 1

The majority of the candidates successfully completed the practical work and were able to gain credit for drawing the graph and the calculation.

(a) Candidates should be reminded to record all thermometer readings to $.0\,°C$ or $.5\,°C$ as the calibration is at $1\,°C$. A few candidates read the thermometer incorrectly as they were a factor of 10 out. Only a minority of candidates gained credit for the second marking point, indicating that many were unaware that the reason for carrying out the extra tests was to identify the maximum temperature more accurately.

(b) Almost all candidates labelled the axes correctly though many chose scales that did not take up at least half of the available space. The plotting was generally good though some candidates became careless towards the end and some used large, often imprecisely placed, blobs to denote the points. Credit for lines of best fit was awarded to only a minority of candidates as many ignored points off the lines or did not have balanced points about the line. Some candidates could not be awarded credit for maximum temperature change as the intercept was below the maximum temperature or they recorded the maximum temperature instead of the change as instructed. Most candidates received credit for accuracy of their experimental results.

(c) Many candidates did not use the total volume of $60 \, cm^3$ in the first part of the calculation. However, most correctly calculated the number of moles of acid used and were able to complete the calculation successfully. Very few did not convert $J \, mol^{-1}$ to $kJ \, mol^{-1}$ and the significant figures shown were largely appropriate for an enthalpy experiment.

Question 2

(a) Despite the clear instruction to record burette readings for the rough titration, some candidates did not do this. There was a large number of candidates (and some Supervisors) who did not record burette readings to .x0 or .x5 cm^3. Since the burette is calibrated at .1 cm^3, all readings should be recorded to the nearest 0.05 cm^3. A majority obtained concordant titres and were able to gain at least partial credit for accuracy. Some candidates showed that the dilution and titration had been carried out with suitable care. However, some candidates produced a large range of titres with few in agreement.

(b) The majority of candidates were able to obtain a suitable value from their data to use in the calculation. Those that did not obtain credit here did not show working, incorrectly used the value from a rough titre, included results with too great a spread, incorrectly rounded for the final answer or gave the final answer to too few decimal places.

(c) A large majority of candidates ignored the dilution factor for the acid so used a concentration of $0.950 \, mol \, dm^{-3}$ instead of $0.0950 \, mol \, dm^{-3}$ in their calculation in **(i)**. Although most were able to use the value obtained correctly in **(ii)** and **(iii)**, many did not give their answers to 3 or 4 significant figures as expected. Most used 6.9 ÷ **(iii)** in **(iv)** but had difficulty progressing further correctly owing to the factor of 10 error. Only a minority of candidates understood that $M_2CO_3(aq)$ would mean that M was a Group 1 metal.

(d) In **(i)** candidates often did not address the 'explain' part of this question. However, many gained the mark in **(ii)**, usually by suggesting the use of extra insulation or a lid to reduce heat losses or by using a burette or pipette to reduce errors in volume measurement.

Question 3

Although some candidates gained full credit, many appeared to have run out of time so parts of the question were omitted. Parts **(c)** and **(d)** were attempted least often.

(b) It was important for the development of the question that candidates followed the instruction to use the minimum quantity of nitric acid to react with the solid residue from **(a)**. Most recorded effervescence in **(i)** but some stated 'gas evolved' without giving evidence. The few who tested the gas with limewater reported the correct result. The majority of candidates noted a white precipitate in **(ii)** but some did not add excess aqueous sodium hydroxide or added insufficient for the volume of acid used in **(i)**. Most of those gaining the expected results were able to state the names or correct formulae of the three possible ions. Candidates obtaining incorrect results in **(ii)** had the opportunity to gain partial credit in **(iii)**. Most suggested using aqueous ammonia to distinguish between Zn^{2+} and the Al^{3+}/Pb^{2+} pair but fewer suggested a second suitable reagent to distinguish between the pair. Many of those suggesting the presence of Ba^{2+}/NH_4^+ or Ca^{2+}/Mg^{2+} in **(ii)** gained partial credit here. A large number of candidates did not record all the expected results of the tests they were to carry out for the possible ions. However, a substantial number were able to identify Zn^{2+} after a successful test with aqueous ammonia. Unfortunately, most candidates who obtained an incorrect or incomplete result in **(ii)** reported results that backed up one of their chosen ions rather than those expected.

(c) Fewer candidates than expected noted a cream precipitate with aqueous silver nitrate although most reported the correct limited solubility of the precipitate in aqueous ammonia. Candidates are expected to be familiar with the tests for halide ions and with the correct terminology. Use of the Qualitative Analysis Notes should be encouraged. A substantial number did not appreciate that the second reagent was to be added to the test-tube containing the precipitate and so mistakenly suggested lead nitrate as the second reagent.

(d) Most of those who noted effervescence or gas turning limewater milky in **(b)(i)** gained credit here.

(e) The majority of candidates gained credit for testing **FA 6** and **FA 7** with aqueous barium chloride/nitrate and hydrochloric acid. The test with aluminium foil was not carried out so well; some candidates did not report that it was a gas turning red litmus blue with **FA 6** or some incorrectly obtained the same result with **FA 7**. Only a minority observed a gas turning brown with **FA 6** in the third test, but candidates could still receive credit for the identity of the nitrite from noting bubbling with acid in either test. Many candidates appeared unsure of the types of reaction; 'neutralisation' and 'displacement' were frequent responses in **(iii)**. While 'redox' was the expected answer, a few candidates were able to gain credit for stating that the aluminium was oxidised.

CHEMISTRY

Key Messages

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- 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 lines of best fit should have balanced points either side of the line with anomalies/outliers ringed or labelled as such.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places.

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

Comments on Specific Questions

Question 1

The majority of the candidates completed the practical work, drew clear, correctly labelled tables, and were able to gain credit for drawing the graph and the calculation.

(a) This question was answered quite well; almost all candidates were awarded at least partial credit for accuracy marks and temperature differences were correctly calculated. However, candidates should be reminded to record all thermometer readings to .0 °C or .5 °C as the calibration is at 1 °C. A few candidates read the thermometer incorrectly as they were a factor of 10 out.

(b) Almost all candidates labelled the axes correctly though a significant number chose scales that did not include the 2 °C above the maximum temperature rise as instructed. The plotting was generally good though some candidates used large, often imprecisely placed, blobs to denote the points. Very few candidates were awarded credit for the lines of best fit as many ignored points off the lines, did not

have balanced points about the lines or forced the intercept to be at the greatest temperature rise recorded. However, the reading of the volume associated with the greatest temperature rise was mostly correct.

(c) The vast majority of candidates were able to calculate the number of moles of acid in the volume recorded in **(b)(iii)** and realised that the same answer was required in **(ii)** as in **(i)**. However, many candidates, having forced their intercept to $14.0\,cm^3$, gave the answers to 2 significant figures instead of the 3 or 4 expected. Many candidates completed **(iii)** correctly though a substantial minority divided by the total volume rather than the volume of **FB 2**, ignoring the reminder given in the question.

(d) Very few candidates gained full credit here. Credit was most commonly awarded for a comparison of accuracy of volume measurement between burette and measuring cylinder and the effect on the overall accuracy of the experiment. Very few candidates appreciated that the increase in volume would have no effect on the increase in temperature. The comments about the greater number of experiments often lacked precision; reference to improvements in finding the intercept on the graph was essential.

Question 2

(a) Despite the clear instruction to record burette readings for the rough titration, some candidates did not do this. There was a large number of candidates (and some Supervisors) who did not record burette readings to .x0 or .x5 cm^3. Since the burette is calibrated at .1 cm^3, all readings should be recorded to the nearest $0.05\,cm^3$. A majority obtained concordant titres and were able to gain at least partial credit for accuracy. Some candidates showed that the dilution and titration had been carried out with suitable care. However, some candidates produced a large range of titres with few in agreement.

(b) The majority of candidates were able to obtain a suitable value from their data to use in the calculation. Those that did not obtain credit here did not show working, incorrectly used the value from a rough titre, included results with too great a spread, incorrectly rounded for the final answer or gave the final answer to too few decimal places.

(c) Although most were able to use the value obtained in **(b)** correctly in **(i)** and **(ii)**, many did not give their answers to 3 or 4 significant figures. A large majority of candidates ignored the dilution factor for the acid so omitted the x10 factor in **(iii)**. However, most candidates showed working in the correct direction and so partial credit was awarded.

Question 3

Although many candidates gave good answers here, some ignored the instruction to give the full name or formula of any reagent selected for a test. Candidates should be encouraged to read through a question before starting any practical work as some wasted time in drawing a table on page 9 then had to copy the results recorded into the table on page 10.

(a) The majority of candidates gained at least half the credit available here. The most common omissions were the precipitate formed with **FB 5** and **FB 6** turning brown and the solubility of precipitates in excess **FB 5**. Some candidates reported a grey-green precipitate formed between **FB 5** and **FB 6** even though Cr^{3+} was not given as an ion present in either **(a)** or **(b)**.

(b) Most candidates received some credit here, even when the reporting of changes in **(a)** had been imprecise.

(c) While candidates should be encouraged to use the Qualitative Analysis Notes, it is important that they note the instruction to use the full name or formula of a reagent selected for a test. Hence, candidates were not awarded credit for copying the test from page 13. Often only the metal ion was given and the strong acid was not specified. Some candidates incorrectly suggested using sulfuric acid in conjunction with aqueous barium chloride/nitrate as a test for sulfate/sulfite. Similarly, some candidates coupled hydrochloric acid with lead ions, ignoring the low solubility of lead chloride at this concentration of chloride ions. A surprising number suggested the sulfate and sulfite could be distinguished by the solubility of any precipitate in excess barium chloride/nitrate. Those who chose to add a named acid often omitted the expected observations: gas evolved is a deduction, effervescence or the gas turned orange acidified potassium dichromate green are observations.

(d)   Candidates provided a wide range of suitable tests though credit often could not be awarded for the reagent through imprecision, for example potassium dichromate/manganate(VII) needs to be <u>acidified</u>. Insufficient precision was also evident in the observations given and incomplete deductions were often made. A number of candidates appeared unaware that PCl_5 would form misty fumes with both ethanol and ethanoic acid. A minority of candidates did not choose a second reagent to distinguish between the pair of liquids remaining. Those selecting 2,4-DNPH followed by Tollens' reagent could not be awarded full credit. However, there were many excellent responses with candidates gaining full credit and giving clear reasons for the results of the tests suggested.

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. Thermometer readings should be recorded to the nearest $0.5\,°C$.
- 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 lines of best fit should have balanced points either side of the line with anomalies/outliers ringed or labelled as such.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places.
- Instructions in the rubric need to be read and acted upon.

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

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

Comments on Specific Questions

Question 1

The majority of the candidates completed the practical work, drew clear, correctly labelled tables, and were able to gain credit for drawing the graph and the calculation.

(a) Almost all candidates recorded the balance readings to the same number of decimal places, recorded the mass of **FA 1** used correctly and noted all the required thermometer readings. However, a minority of candidates did not record all thermometer readings to $.0\,°C$ or $.5\,°C$, as is expected with a calibration at $1\,°C$, or recorded all of the 8 readings at $.0\,°C$. The majority of candidates gave suitable headings to their tables and displayed the units of mass and temperature correctly. Very few candidates were not awarded credit for accuracy and in fact many obtained full credit.

(b) Almost all candidates labelled the axes correctly though a significant number chose scales that did not occupy over half the available space as they started the temperature axis at $0\,°C$. The plotting was

generally good though some candidates were imprecise in the placing of points and some used large blobs to denote points which were not centred in the correct position. Credit for lines of best fit was awarded to the majority of candidates though some did not have balanced points for the second line or had a positive gradient for both lines. Credit was least frequently awarded for the temperature change at 2½ minutes. This was owing to a large minority of candidates not extrapolating the two lines to that time and by using a line with positive gradient joining the point at 2 minutes with that at 3 minutes.

(c) Candidates should be encouraged to read through practical instructions completely before starting work. A significant number of candidates incorrectly started recording thermometer readings every minute as in **(a)** which was unnecessary and costly in terms of time. There was evidence from some that insufficient stirring was carried out. However, many candidates gained full credit as they drew suitable tables and the accuracy was good.

(d) While most candidates calculated the heat energy produced or absorbed in **(i)** and **(iii)** correctly, some used the mass of solid instead of the volume of solution even though the specific heat capacity was given in $J\,cm^{-3}\,°C^{-1}$. Most candidates correctly calculated the formula masses of **FA 1** and **FA 2** and many answered **(ii)** and **(iv)** in two stages, first calculating the number of moles used and then calculating ΔH. This is clearly acceptable but care must be taken not to approximate intermediate answers to too few significant figures. Most candidates converted J to kJ and recorded the correct signs in **(ii)** and **(iv)**. The last part of the calculation proved more challenging for some as a number of Hess' law diagrams were incorrectly drawn so the final answer was incorrect. Credit was frequently awarded for working as most candidates showed working in the correct direction in their calculations. Credit for appropriate significant figures was less frequently awarded.

(e) Many candidates gained full credit in this section but there are still some who appear unaware that the maximum error in calibrated apparatus is ± half the smallest division or that a temperature change involves two thermometer readings. Credit in **(ii)** was available as error carried forward, and only very few did not use the temperature change from **step 2** in their calculations.

(f) The majority of candidates stated that the student in **(i)** was incorrect but many did not continue with a valid reason for this. Only the clearest thinking candidates were able to gain full credit in **(ii)** and most did not gain any. The majority found the mean mass and mean temperature which was not a valid approach. Of those who treated the two sets of results individually, many used a formula mass from **(d)** to help them calculate ΔH values and only a few used the more elegant method of comparing ratios. However, the majority of those treating the results individually were awarded full credit.

Question 2

Although many candidates gave good answers here, some ignored the instruction to give the full name or formula of any reagent selected for a test. Use of the Qualitative Analysis Notes helps with the descriptions of precipitates formed with aqueous sodium hydroxide and ammonia.

(a) Almost all candidates gained at least partial credit here. The most common omission was that the precipitate formed with **FA 4** turned brown in air. Some of the descriptions of the precipitates did not agree with the wording in the Qualitative Analysis Notes.

(b) Almost all candidates selected to use the products with excess sodium hydroxide but some omitted the necessity of heating the mixture. A more common error was not specifying that it is the gas that should be tested with red litmus paper. Almost all candidates were able to identify **FA 4** as having a positive result but a significant number also identified ammonia being evolved from one or both of the other mixtures indicating a lack of care when carrying out the procedure.

(c) It is important that candidates note the instruction to use the full name or formula of a reagent selected for a test; there were many instances of Ba^{2+} or OH^-. Many candidates selecting aqueous lead nitrate appeared unaware that a white precipitate may form with the chloride as well as the sulfate and so did not gain full credit for observations. Again, it was important to specify that it was the gas which turned red litmus blue when warming with sodium hydroxide and aluminium. Those who tested for chloride/sulfate initially were at an advantage as the third test did not have to be carried out on any other than **FA 5**. Those testing all three solutions, even when this test was carried out last, often missed the evolution of ammonia with **FA 4**. Candidates should be encouraged to read the instructions carefully as they were asked to 'identify positively' which anion was in each salt and some deduced nitrate in **FA 5** by elimination.

(d)   Almost all candidates gained at least partial credit for the deductions. The marking point least often credited was for the cation in **FA 5** as many omitted either Pb^{2+} or Al^{3+}. The other common error was either to omit NH_4^+ or place it in more than one salt. However, most candidates were able to deduce that **FA 4** contained Fe^{2+} and SO_4^{2-} and that **FA 3** contained Cr^{3+} and Cl^-. Slightly less common was that only **FA 5** contained NO_3^-. However, there was no evidence that candidates were rushed at the end of the paper.

CHEMISTRY

> **Paper 9701/41**
>
> **A2 Structured Questions**

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.

- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.

- Candidates should set out calculations which clearly explain what the numbers refer to.

- Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly in organic chemistry.

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.

The answers to the questions in **Section B** were generally of a higher standard than previously, and the overall neatness and legibility of answers was good. This was not always the case, however and candidates are reminded to make sure that their desired final answers are obvious to the Examiner and legible.

The arithmetical working in calculation questions should be set out clearly, to allow Examiners to award credit for 'error-carried-forward' wherever possible.

Candidates are also reminded of the importance of careful reading of the question thoroughly before attempting to answer it, underlining key words or phrases on the question paper to ensure they answer in the correct manner.

Candidates need to read the questions carefully before answering them. Questions where this was noticed were:

Question 1(b) – this required a fully-labelled diagram to be included.
Question 2(a)(ii)(iii) –construction lines were required to be drawn on the graphs.
Questions 3(b) and **6(a)** – candidates were asked to place only one tick against each reaction or substance.
Question 8(c) – candidates were asked to link the structure of the polymer to why the gel could be easily washed out of hair.

This report should be read in conjunction with the published mark scheme for this paper, which offers accepted answers to the questions.

Comments on Specific Questions

Section A

Question 1

(a) Quite a number of candidates omitted the conditions for the measurement of a standard electrode potential.

(b) Most candidates gained some credit here. The most common errors were using an iron electrode (instead of a platinum electrode) and omitting Fe^{3+} or Fe^{2+} in the Fe^{3+}/Fe^{2+} half of the cell. Some candidates also erroneously included a battery in their circuit. Many candidates remembered to include a salt bridge and a good delivery system for the hydrogen gas.

(c)

(i) Candidates usually carried out the calculation correctly.

(ii) This was generally well answered, though some candidates did not refer to their answer in **(c)(i)**.

(iii) Most candidates gave a correct expression and units for K_c.

(iv) This proved a trickier question with only the more able candidates gaining full credit. The most common error was in candidates suggesting that $[Fe^{2+}] = [Fe^{3+}]$ (2.0×10^{-4} mol dm^{-3}) and calculating $[I^-]$ to be 0.02 mol dm^{-3}.

(v) Most candidates scored well here, as credit for error carried forward was available for those who had miscalculated $[Fe^{2+}]$ and $[I^-]$ in **(c)(iv)**.

Question 2

(a)

(i) This was generally well answered, though it was surprising how many candidates made a plotting error. The most common errors were plotting the points at 25 min and 125 min, or drawing a best fit straight line.

(ii) Many candidates scored credit here, however the answers of some candidates were difficult to decipher. Candidates need to make sure that their desired final answers are obvious to the Examiner and legible.

(iii) This proved difficult for many candidates with only the more able candidates gaining full credit. Many candidates did not recognise that they had to compare the results from both graphs. In addition only a small number managed to calculate the rate from a concentration-time graph correctly.

(iv) Most candidates scored some credit here, as credit for error carried forward was available for the rate equation. Only the stronger candidates calculated a rate correctly and used this value to calculate k.

(b)

(i) A good number of candidates managed to suggest a valid reason of why the order of reaction with respect to water was not possible to determine in this experiment.

(ii) Almost all of candidates gave the correct answer here.

Question 3

(a)

(i) Most candidates gave the correct answer here.

(ii) Many candidates performed well here.

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(b) Almost all candidates gained some credit here. This was well-answered by well-prepared candidates but a significant number of others seemed to guess at the correct answers.

(c) Many candidates scored well here, as credit for error carried forward was available for those who had miscalculated the moles of Al. The most common error was 13.5%, where candidates had multiplied the moles of hydrogen by 1.5 instead of ⅔.

Question 4

(a) Almost all gave the correct answer here.

(b)

(i) The balancing of the equation was well done by most candidates.

(ii) Pleasingly, most candidates gave the details that lightning or the combustion of fossil fuels were common sources of nitrogen oxides. Quite a few candidates stated that nitrogen oxides were formed in a catalytic convertor which is incorrect.

(iii) Many candidates knew that acid rain was a main environmental effect of nitrogen oxides in the atmosphere.

(c) Only a few candidates gained full credit here. It seemed that a lot of candidates guessed the order. Many candidates gained some credit for knowing that alkyl groups were electron-donating (not 'repelling') and that in phenylamine the lone pair is delocalised over the benzene ring.

(d)

(i)(ii) Only a fraction of candidates gained full credit here. A common error in **(d)(i)** was step 2 being classified as an oxidation reaction. In **(d)(ii)** although stronger candidates knew the reagents and conditions for both reactions, weaker candidates often omitted one or both, for example not mentioning heat in both steps or that step 2 must be done under aqueous conditions.

(iii) This proved a trickier question with only the more able candidates suggesting a correct structure for both intermediates. The most common errors were omitting a CH_2 group in the structure of **T** and suggesting that structure **W** was an amide.

Question 5

(a) Almost all candidates gained some credit here. However, it seemed that a lot of candidates guessed whether a gas was produced or not.

(b)

(i) Many candidates identified the correct reagent here. The common error was C_4H_9Cl, which was not sufficient.

(ii) A pleasing number of candidates correctly stated that this reaction is reduction (or hydrogenation). Stating that this was an addition reaction was not sufficient.

(iii) This proved a tricky question with only the more able candidates suggesting the correct reagents and conditions for step 3. Weaker candidates often omitted 'heat' or 'aqueous' with their acid.

(iv) Many candidates gained some credit here, although some again omitted 'heat' or 'aqueous' with their acid.

(c)

(i) There were a number of good answers to this part, although others found this quite difficult. Many candidates seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. Candidates had most difficulty with the structures from the reactions of the various reagents with **B**, for example some candidates incorrectly suggested that the reaction of acidified $K_2Cr_2O_7$ with **B** would produce a carboxylic acid.

(ii) Many candidates recognised that aqueous bromine can be used to distinguish between **A** and **B**. A common error was stating the colour change of acidified $K_2Cr_2O_7$ with aqueous Br_2.

Section B

Question 6

(a) This was well answered with most candidates receiving full credit.

(b) The key to this part was to recognise that hydrogen bonding maintains the helical structures of proteins and DNA. Most candidates showed some knowledge about the helical structure of DNA, however far fewer correctly identified that hydrogen bonds with –NH and C=O groups on different amino acids maintained the helical structure of protein. Many candidates incorrectly gave an answer about the different types of structure in a protein.

(c) Almost all candidates gained some credit here. The most common errors were stating that the primary structure is maintained by hydrogen bonding, and in the tertiary structure omitting the types of amino acid that are responsible for the bonding.

Question 7

(a) This question was answered well. The majority of the candidates gave some very good answers. The most common mistakes were omitting the extracting DNA, using the polymerase chain reaction and labelling the fragments with a radioactive isotope such as ^{32}P.

(b) Many candidates performed well here.

(c) Again, many candidates gained full credit.

Question 8

(a)
> **(i)** This question was not answered well. The most common errors were omitting continuation bonds and drawing a condensation-type polymer.
>
> **(ii)** Many candidates did not correctly identify the type of polymerisation. Common errors were additional and condensation.
>
> **(iii)** Almost all candidates gained credit here.

(b)
> **(i)** This proved difficult for many candidates who could not relate the structures of the two polymers to the way they might affect the water absorbing properties, i.e. that the polymer made from sodium propenoic acid would be more polar and would be more water absorbing.
>
> **(ii)** This was answered well by candidates.

(c) This proved a tricky question with only the more able candidates suggesting that heavy metals ions would undergo ion exchange with the Na^+ ions in the gel. Only a handful recognised that the propenoate ion would attract the heavy metal ions to facilitate this exchange.

(d)
> **(i)** This question was answered well. Many candidates identified this type of reaction as condensation or esterification.
>
> **(ii)** Most candidates identified that hydrogen bonds would form between the polymer and water, but they did not link to the OH/alcohol group in the polymer.

CHEMISTRY

| **Paper 9701/42** |
| **A2 Structured Questions** |

Key Messages

- Candidates should be reminded to use the correct number of significant figures during and at the end of a calculation.

- The setting-out of calculations needs to be clear and logical to allow Examiners to follow candidates' working and award credit for work done even if the final answer is incorrect.

- Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A2 examination, particularly in organic chemistry.

- Candidates need more practice in the interpretation of NMR spectra and in the prediction of mass spectra: in particular, the chemical shift values given in the *Data Booklet* need to be used with care, so that conclusions are considered in relation to other structural data given in the question.

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 general evidence of candidates running out of time. The answers to the 'Applications' questions in **Section B** were generally of a higher standard than previously and the overall neatness and legibility of answers was also good.

This report should be read in conjunction with the published mark scheme for this paper, which offers accepted answers to the questions.

Comments on Specific Questions

Section A

Question 1

(a) Most candidates wrote a correct balanced equation in **(i),** although some incorrectly gave RONa or HCl as products. Most also correctly described the reaction type as nucleophilic substitution, although some suggested electrophilic substitution. 'Hydrolysis' was not accepted, as the stem of the question already stated that RBr was being hydrolysed.

(b)
    (i) The plotting caused few problems, but several candidates did not show the point plotted at t = 0. Quite a number thought the line of best fit should be a straight line, however, rather than the smooth curve required.

    (ii) The easiest way to confirm a first order reaction would have been to construct lines to measure and compare two half-lives. Many candidates did this successfully.

    (iii) Candidates were less successful in this part. Several measured half-lives again, and stated that because they were constant, the reaction was first order in [OH⁻], not realising that all they had done was to confirm for a second time that the reaction was first order in [RBr]. Successful

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candidates either measured and compared **initial** rates, or the rates (= tangents) at points where [RBr] had fallen to the **same level**, or showed that the half-lives in the two experiments were in a 1:1.5 ratio. Some candidates measured the rates of the two experiments after the same **time** had elapsed, with erroneous conclusions. Quite a number of candidates did not draw tangents, but calculated (average) rates from (change of concentration)/time, which often did not produce valid data. Some even merely calculated concentration/time values from the table, which had nothing to do with actual rates.

(iv) Credit for error-carried-forward was awarded here if the candidate had calculated an incorrect order in **(iii)**. Most candidates gained credit for the rate expression (although some did not include the 'k'), but fewer calculated the value of k correctly.

(c) Most candidates scored well on this part. The most common error was in not labelling ΔH correctly; several showed it as if it were the activation energy for the reverse reaction. Both E_a and ΔH should have been indicated by drawing arrows starting and finishing at the correct places; the first pointing upwards and the second pointing downwards.

Question 2

(a)

(i) Most candidates gained at least half of the credit available for this part. Common errors were not indicating that H_2 was a gas; showing it as being evolved rather than bubbled into the solution; drawing the gas delivery system with a top open to the air (so that any $H_2(g)$ flowing in through the side arm would have gone straight into the atmosphere); not showing the platinum foil at the surface of the liquid - or not even showing that the liquid had a surface. Some stated that the standard temperature was 273 K rather than 298 K. Others who used $H_2SO_4(aq)$ as the solution stated its concentration should be $1.0\,mol\,dm^{-3}$ rather than $0.5\,mol\,dm^{-3}$.

(ii) Most correctly calculated the $E^{\oplus}$, but quite a number of candidates suggested Cr(s) was oxidised to Cr^{2+}, or Cr^{3+} reduced to Cr^{2+}, or did not balance the equation.

(iii) Many gained credit for the final colour being green, but several did not mention the starting colour was orange. Some mentioned the blue of Cr^{2+}, but not the orange of $Cr_2O_7^{2-}$.

(b) This was a fairly straightforward calculation, as long as candidates were clear as to how to use the buffer equation in calculations. There were two general methods they could have used. One used the buffer equation pH = pK_a + log([salt]/[acid]); the other used the non-logarithmic version [salt]/[acid] = $K_a/[H^+]$. In either case, it was important to realise that [salt] was not equal to $[H^+]$ (as it is in the approximate equation for weak acids, $[H^+]^2 = K_a[HA]$). Many candidates correctly calculated the [salt]/[acid] ratio as 5.66, but then either could not change this into the volumes of solution, or inverted the ratio and quoted the volume of acid as $85\,cm^3$ and that of the sodium ethanoate solution as $15\,cm^3$.

(c) Whilst many candidates did give two correct equations here, there were several who only gained partial credit. Either they suggested that the acyl chloride was the product with HCl, or that the second equation started with the ionised weak acid, or omitted H_2O as one of the products.

(d) This part allowed candidates freedom to choose a reaction known to them. Credit was not awarded if they quoted a reaction that involved H^+ as a reagent rather than as a catalyst. Thus oxidations with dichromate or reactions with RONa or RCO_2Na were not accepted. Esterification, ester or amide hydrolysis, nitration of arenes and hydration of alkenes were all given credit. Several candidates did not mention the NH_3 (or NH_4^+) product of the hydrolysis of amides.

Question 3

(a) Most candidates knew the reagents in **(i)**; conditions needed were *concentrated*, at a *temperature below 60°C*. In **(ii)** many candidates used the same reagents and conditions, rather than *dilute* HNO_3 at *room temperature*.

(b) A significant number of candidates were not awarded credit; common errors were charges on the H and NO_2 joined to the sp^3 carbon, incorrect connectivity of the $-NO_2$ to the ring (e.g. NO_2-Ar rather than

O_2N-Ar), or the positive charge shown not in the 'horseshoe' of delocalised electrons, but near the sp^3 carbon.

(c) This was well answered by the majority of candidates, although some suggested $LiAlH_4$, or H_2. A significant number described the tin as a catalyst, rather than a reagent.

(d)

(i) The structure of compound **A** (tribromophenylamine) was known by many, but fewer were able to draw a correct structure for the azo dye **B**. Many structures were seen that included the -N=N-O-Ar grouping. Others incorrectly showed a covalent bond between the Ar-O⁻ and the Na⁺.

(ii) The reagent here (HNO_2 or $NaNO_2 + HCl$) was well known by most, but there were a significant number of candidates who suggested HNO_3, or $NaNO_3$. The temperature ($<10\,^{\circ}C$) was also recalled well, though those candidates who suggested 'reflux at $10\,^{\circ}C$' clearly had little idea of what the word 'reflux' means.

(e) Many recognised the amide group in **(i)**, and the majority of candidates correctly calculated the percentage of N in **(ii).** Some incorrectly calculated the percentage of carbon. The structural formula in **(iii)** was worked out accurately by most.

Question 4

(a)

(i) Only a few candidates gained credit here. The key point to mention was either that for transition elements there are no big jumps in their successive ionisation energies, or that the 4s and 3d orbitals are of similar energies. Most candidates merely stated that transition elements contain d-orbitals whereas s-block elements do not.

(ii) By contrast, all candidates gained at least partial credit here, and most were awarded full credit.

(b) There were five marking points identified here, the mention of four of which would gain candidates full credit. There was confusion apparent between colour being the complement of the colour(s) absorbed, rather than being due to the emission of light as the electron falls back down to a lower level. The other seldom-gained marking point, that in s-block elements the energy gap between the highest occupied orbital and the lowest unoccupied one is too large for the energy of transition to correspond to visible frequencies of light, was little understood by almost every candidate. Most merely re-stated that s-block elements do not contain d-orbitals.

(c)

(i) The use of $KMnO_4$ in acidic solution as an oxidising agent should have been well-known by candidates, but several suggested that the final product would be MnO_2 rather than $Mn^{2+}(aq)$.

(ii) Several candidates thought that this question involved the end-point of a $KMnO_4$ titration, so gave the colour change as "colourless to first permanent pale pink". 'Purple to colourless' was the correct answer.

(d) One important observation that many candidates forgot to mention was that the initial solution is coloured pale blue. Thereafter most correctly stated that a pale blue precipitate (of $Cu(OH)_2(s)$) would form, followed by its re-dissolving to form a deep blue solution (of $(Cu(NH_3)_4)^{2+}(aq)$).

Question 5

(a)

(i) There are four chiral centres in chlorogenic acid. Many candidates found all four, although some did not spot the two ring atoms attached to the –OH groups. Others circled incorrect atoms – the two on the alkene bond were the most common.

(ii) There were not many correct molecular formulae seen by Examiners, the most common errors being to miscount the hydrogen or the carbon atoms.

(iii)   Each –OH group reacts with Na to give ½ H_2, and so there will be 3 moles of $H_2(g)$ formed from the six groups. Answers varied from 3 to 6.

(iv)   The alcoholic –OH groups do not react with NaOH(aq), so only the phenolic –OH and the carboxylic acid would react, with 3 moles of NaOH in the cold. On heating, the ester group would hydrolyse, giving an alcohol (inert to NaOH(aq)) and a carboxylic acid, which will have reacted with NaOH to give the salt R-CO_2Na. Thus 4 moles of NaOH would react on heating. Several candidates realised that an extra mole of NaOH would be needed, and were therefore able to gain credit for realising this, even if they did not have the correct answer to the 'in the cold' situation.

(b)

(i)   Although many candidates correctly identified this as a hydrolysis reaction, there were several who incorrectly suggested 'condensation', 'reduction', or the catch-all 'de-esterification'.

(ii)   Quite a number of candidates suggested 'alcohol', 'secondary alcohol' or 'ketone' for this part, rather than the correct 'alkene'.

(iii)   The **names** were required, rather than just the formulae. The full name 'carboxylic acid' was needed for the first response, and 'phenol' (not just 'arene') for the second. There were many candidates who suggested 'alkene' for the second response, despite their having written 'alkene' in (ii), and hence had eliminated it as a possible functional group.

(iv)   A significant number of candidates kept the tertiary –OH group in their structures for **F**, which almost always produced a compound with a 5-valent carbon atom. There were two marking points available for the structure of **G**: one for adding 2 x Br (or Br + OH) across the C=C, and the other for incorporating two or three Br atoms in the benzene ring. Most candidates were awarded at least partial credit here.

(v)   Cis-trans, geometrical or E-Z were all acceptable answers here. Several candidates incorrectly suggested optical isomerism.

(c)   Many gave correct answers to this calculation; the most common errors being to miscalculate the M_r value for **E**, and not to realise that 1 mole of **E** would react with 3 moles of NaOH.

Section B

Question 6

(a)   Almost all candidates scored well on this part, although there was some confusion between cysteine and cytosine.

(b)

(i)   Most candidates correctly identified hydrogen bonding between the bases on the chains.

(ii)   The important point was that the hydrogen bonding is weak enough to allow the chains to unwind during replication. Some candidates did not express this clearly enough

(c)   Most candidates gained at least partial credit here, but many did not give as coherent an answer as was required for full credit. Some incorrectly suggested that mutations *caused* changes in DNA, or that changes in the amino acid sequence in the polypeptide caused changes in the base sequence of DNA. Others confused the two polymers completely, and wrote about changing the sequence of the 'amino acid bases in DNA'.

Question 7

(a)

(i)   The calculation of the number of carbon atoms was carried out successfully by almost all candidates.

(ii)   Although many candidates stated that the halogen was chlorine, far fewer gave the reason: that the M:M+2 ratio was 3:1.

(iii)   Most candidates correctly deduced that there were seven protons in three different chemical environments.

(iv)   Candidates tended to use the data given to them, both that given in the question, and that found in the *Data Booklet*, without checking that the various pieces of data fitted in with each other. Thus the multiplet at $\delta 7.3$ could not be the –OH of a phenol, as it arises from *four* hydrogen atoms. Hence it shows a di-substituted benzene ring; the peak at $\delta 4.7$ cannot be a phenolic -OH, as its integration value shows it to be due to *two* protons, not one; the peak at $\delta 2.3$ cannot be Ar-CH$_3$ as it arises from only *one* proton, not three. Furthermore, it cannot be a phenolic –OH because its δ value is too high. Candidates needed to know that the δ values for functional groups are usually shifted downfield (to higher δ values) by the presence of a benzene ring. Only a few explicitly stated that **L** must contain a single oxygen atom, both from the M_r data, and also from its reaction with sodium. Many appreciated that since the peak at $\delta 4.7$ was a singlet, it must contain a -CH$_2$- group with no adjacent H atoms. The structure of **L** was therefore Cl-C$_6$H$_4$-CH$_2$OH.

(b)
(i)   Many candidates seemed to mix up the mass spectrum and the NMR spectrum, and stated that the mass spectrum of cyclopropane would consist of a single peak, whereas that of propene would have three peaks. The more perceptive candidates realised that there should be a peak at m/e 15 in the spectrum of propene, due to CH$_3^+$, which ought to be absent from the mass spectrum of cyclopropane.

(ii)   Most candidates appreciated that all six protons in cyclopropane are equivalent, and so the NMR spectrum would show a singlet, whereas that of propene would contain a peak due to the -CH$_3$ group (at $\delta 1.0 – 2.0$) and various alkene-H peaks in the region $\delta 4.5$-6.0.

Question 8

(a)   Many candidates found it difficult conceptually to separate the horizontal chains from the (vertical) cross-linking. The mark scheme was designed to allow *some* credit for this misinterpretation, however. Able candidates recognised the monomer in **(i)** as CH$_2$=CHCO$_2$H, and stated in **(ii)** that the chains were formed by addition polymerisation, with the cross-linking molecule in **(iii)** being C(CH$_2$OH)$_4$.

If candidates thought the 'chains' were vertical ones, they described the monomers as C(CH$_2$OH)$_4$ and "-CH$_2$CH(CO$_2$H)CH$_2$CH(CO$_2$H)-". Clearly this latter "monomer" was not a discrete molecule. This misinterpretation did not allow for a sensible cross-linking molecule in **(iii)**.

In **(iv)** most candidates gained credit for H$_2$O.

(b)   The key points were that the water would be *hydrogen-bonded* to the gel, and the *relatively weak* hydrogen bonds would allow the water to be easily lost on drying. Many candidates gained credit for the first marking point, but not the second. A significant number incorrectly thought that the water was absorbed through the hydrolysis of the ester bonds, which would re-form on drying.

(c)
(i)   Only a few candidates appreciated that each cross-linking destroys two –OH groups from the -CO$_2$H side groups of the chains, but adds two more –OH groups from the C(CH$_2$OH)$_4$, thus maintaining the number of –OH groups.

(ii)   Candidates were expected to appreciate that cross-linked polymers are usually more rigid, harder and stronger than linear polymers, due to the chains being more tightly held together.

CHEMISTRY

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.

- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.

- Candidates should set out calculations which clearly explain what the numbers refer to.

- Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly in organic chemistry.

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This report should be read in conjunction with the published mark scheme for this paper, which offers accepted answers to the questions.

Comments on Specific Questions

Section A

Question 1

(a)   Quite a number of candidates omitted the conditions for the measurement of a standard electrode potential.

(b)   Most candidates gained some credit here. The most common errors were using an iron electrode (instead of a platinum electrode) and omitting Fe^{3+} or Fe^{2+} in the Fe^{3+}/Fe^{2+} half of the cell. Some candidates also erroneously included a battery in their circuit. Many candidates remembered to include a salt bridge and a good delivery system for the hydrogen gas.

(c)

   (i)   Candidates usually carried out the calculation correctly.

   (ii)   This was generally well answered, though some candidates did not refer to their answer in **(c)(i)**.

   (iii)   Most candidates gave a correct expression and units for K_c.

   (iv)   This proved a trickier question with only the more able candidates gaining full credit. The most common error was in candidates suggesting that $[Fe^{2+}] = [Fe^{3+}]$ (2.0×10^{-4} mol dm^{-3}) and calculating $[I^-]$ to be 0.02 mol dm^{-3}.

   (v)   Most candidates scored well here, as credit for error carried forward was available for those who had miscalculated $[Fe^{2+}]$ and $[I^-]$ in **(c)(iv)**.

Question 2

(a)

   (i)   This was generally well answered, though it was surprising how many candidates made a plotting error. The most common errors were plotting the points at 25 min and 125 min, or drawing a best fit straight line.

   (ii)   Many candidates scored credit here, however the answers of some candidates were difficult to decipher. Candidates need to make sure that their desired final answers are obvious to the Examiner and legible.

   (iii)   This proved difficult for many candidates with only the more able candidates gaining full credit. Many candidates did not recognise that they had to compare the results from both graphs. In addition only a small number managed to calculate the rate from a concentration-time graph correctly.

   (iv)   Most candidates scored some credit here, as credit for error carried forward was available for the rate equation. Only the stronger candidates calculated a rate correctly and used this value to calculate k.

(b)

   (i)   A good number of candidates managed to suggest a valid reason of why the order of reaction with respect to water was not possible to determine in this experiment.

   (ii)   Almost all of candidates gave the correct answer here.

Question 3

(a)

   (i)   Most candidates gave the correct answer here.

   (ii)   Many candidates performed well here.

(b)   Almost all candidates gained some credit here. This was well-answered by well-prepared candidates but a significant number of others seemed to guess at the correct answers.

(c)   Many candidates scored well here, as credit for error carried forward was available for those who had miscalculated the moles of Al. The most common error was 13.5%, where candidates had multiplied the moles of hydrogen by 1.5 instead of ⅔.

Question 4

(a)   Almost all gave the correct answer here.

(b)

    (i)   The balancing of the equation was well done by most candidates.

    (ii)   Pleasingly, most candidates gave the details that lightning or the combustion of fossil fuels were common sources of nitrogen oxides. Quite a few candidates stated that nitrogen oxides were formed in a catalytic convertor which is incorrect.

    (iii)   Many candidates knew that acid rain was a main environmental effect of nitrogen oxides in the atmosphere.

(c)   Only a few candidates gained full credit here. It seemed that a lot of candidates guessed the order. Many candidates gained some credit for knowing that alkyl groups were electron-donating (not 'repelling') and that in phenylamine the lone pair is delocalised over the benzene ring.

(d)

    (i)(ii)   Only a fraction of candidates gained full credit here. A common error in **(i)** was step 2 being classified as an oxidation reaction. In **(d)(ii)** although stronger candidates knew the reagents and conditions for both reactions, weaker candidates often omitted one or both, for example not mentioning heat in both steps or that step 2 must be done under aqueous conditions.

    (iii)   This proved a trickier question with only the more able candidates suggesting a correct structure for both intermediates. The most common errors were omitting a CH_2 group in the structure of **T** and suggesting that structure **W** was an amide.

Question 5

(a)   Almost all candidates gained some credit here. However, it seemed that a lot of candidates guessed whether a gas was produced or not.

(b)

    (i)   Many candidates identified the correct reagent here. The common error was C_4H_9Cl, which was not sufficient.

    (ii)   A pleasing number of candidates correctly stated that this reaction is reduction (or hydrogenation). Stating that this was an addition reaction was not sufficient.

    (iii)   This proved a tricky question with only the more able candidates suggesting the correct reagents and conditions for step 3. Weaker candidates often omitted 'heat' or 'aqueous' with their acid.

    (iv)   Many candidates gained some credit here, although some again omitted 'heat' or 'aqueous' with their acid.

(c)

    (i)   There were a number of good answers to this part, although others found this quite difficult. Many candidates seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. Candidates had most difficulty with the structures from the reactions of the various reagents with **B**, for example some candidates incorrectly suggested that the reaction of acidified $K_2Cr_2O_7$ with **B** would produce a carboxylic acid.

(ii)   Many candidates recognised that aqueous bromine can be used to distinguish between **A** and **B**. A common error was stating the colour change of acidified $K_2Cr_2O_7$ with aqueous Br_2.

Section B

Question 6

(a)   This was well answered with most candidates receiving full credit.

(b)   The key to this part was to recognise that hydrogen bonding maintains the helical structures of proteins and DNA. Most candidates showed some knowledge about the helical structure of DNA, however far fewer correctly identified that hydrogen bonds with –NH and C=O groups on different amino acids maintained the helical structure of protein. Many candidates incorrectly gave an answer about the different types of structure in a protein.

(c)   Almost all candidates gained some credit here. The most common errors were stating that the primary structure is maintained by hydrogen bonding, and in the tertiary structure omitting the types of amino acid that are responsible for the bonding.

Question 7

(a)   This question was answered well. The majority of the candidates gave some very good answers. The most common mistakes were omitting the extracting DNA, using the polymerase chain reaction and labelling the fragments with a radioactive isotope such as ^{32}P.

(b)   Many candidates performed well here.

(c)   Again, many candidates gained full credit.

Question 8

(a)

(i)   This question was not answered well. The most common errors were omitting continuation bonds and drawing a condensation-type polymer.

(ii)   Many candidates did not correctly identify the type of polymerisation. Common errors were addition<u>al</u> and condensation.

(iii)   Almost all candidates gained credit here.

(b)

(i)   This proved difficult for many candidates who could not relate the structures of the two polymers to the way they might affect the water absorbing properties, i.e. that the polymer made from sodium propenoic acid would be more polar and would be more water absorbing.

(ii)   This was answered well by candidates.

(c)   This proved a tricky question with only the more able candidates suggesting that heavy metals ions would undergo ion exchange with the Na^+ ions in the gel. Only a handful recognised that the propenoate ion would attract the heavy metal ions to facilitate this exchange.

(d)

(i)   This question was answered well. Many candidates identified this type of reaction as condensation or esterification.

(ii)   Most candidates identified that hydrogen bonds would form between the polymer and water, but they did not link to the OH/alcohol group in the polymer.

CHEMISTRY

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Planning, Analysis and Evaluation

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Key Messages

- As always, candidates should be encouraged to read each question carefully before answering.

- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.

- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

General Comments

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

In the planning question (**Question 1**) candidates need to be strongly advised to read all the information provided before attempting an answer. It seems that high scoring answers are associated with following the information provided. The plan required a knowledge of iodiometric titrations and the ability to organise the points of a lengthy response. The stem of the question provided six bullet point prompts which candidates should be advised to address in their responses. Candidates should be positively directed to respond to these bullet points.

In **Question 2**, two points about data tables are common every session. Firstly, candidates need to fully label each new column used with given requirements. Secondly, the data needs to be correctly quoted, to either a specified number of decimal places or significant figures. In this examination, the data requirement in moles was for three significant figures. There was evidence that some candidates wrongly believe that the number of decimal places is the same as significant figures.

Comments on Specific Questions

Question 1

(a)

    (i) The intent of this question was to apply Le Chatelier's Principle to an exothermic solubility. Most candidates correctly deduced that a temperature increase would decrease solubility by way of promoting the endothermic (backwards) reaction.

    (ii) The requirement of the sketch graph was to graphically illustrate the prediction made in **(ii)**. The axes of a sketch graph always need to be labelled as requested in the stem of the question. It is usual to label the *x*-axis as the independent variable and the *y*-axis with the dependent variable which in this case were temperature and solubility respectively but either way round was accepted. Some candidates had ΔH as a label instead of solubility. The correct prediction of a straight line or curve of negative gradient with no plateau was given by many and received credit. Some had lines with a maximum or a plateau. If candidates gave increasing in **(i)** then the inverse was accepted as error carried forward. The second marking point was less often credited. The line drawn needed to show solubility at 0 °C and 100 °C, so the line given had to be drawn between these two points and often was not. Also there had to be some indication (by say, co-ordinates) of the $5\,g\,cm^{-3}$ solubility at 25 °C by way of numbers on both axes. This was often not done.

(b) Most candidates identified the independent and dependent variables correctly.

(c)   There was a great deal of information provided in this question which was intended to provide a framework for the candidate to use in their answer. The majority of candidates did not follow these leads so missed essential components that were necessary to their response. Thus there was a variable use of the bullet points provided. The most successful responses closely followed these points, often with the candidate addressing each point one at a time.

Some examples of this omission were in the provision of materials. Some candidates gave passing chlorine through water and references to gas syringes even though the question gave a supply of saturated chlorine solution. Others detailed a way of producing solid sodium thiosulfate from a variety of chemicals or even describing how to dehydrate sodium thiosulfate which was entirely unnecessary since the correct reagent was provided. Finally, some candidates attempted to use the potassium iodide solution as the titrant even though it was given as concentrated (with no specific concentration).

It seemed that only a few candidates had any experience with iodometric titrations so the majority of candidates struggled, even though four of the marking points required no specific knowledge of such titrations and could have been gained from general titration principles. Most candidates answered as if the titration was an acid/base titration.

(i)   Very few gave a comprehensive list of apparatus and fewer gave appropriate volumes for the important pieces. Even though the mark scheme was confined to pipettes and burettes with a reasonable stated volume, very few candidates gained credit here.

(ii)   Only a minority of candidates realised that starch was the indicator here and fewer that it was blue/black or colourless. The majority gave an acid/base indicator or some reagent such as potassium permanganate which is not an indicator for this reaction.

(iii)   It was very disappointing to see that the majority of candidates who attempted to correctly divide 5 by the M_r of chlorine actually used the A_r, 35.5 instead. Some presented their answer as a mole value rather than a concentration in $mol\,dm^{-3}$.

(iv)   There were two marking points specified here; the first for defining the parameters of a volumetric solution and the second for a solution that would titrate with the chlorine solution in approximately equal volumes. Often the solution volume, concentration and/or mass unit were missing for the first marking point. Many candidates attempted lengthy, involved calculations involving moles of chlorine and thiosulfate in titres and aliquots which did not usually produce a result.

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(vi)   The requirement here was for an outline calculation only, which could be a fairly straightforward description or the use of sample numbers. This was not often attempted.

(d)   The hazards and precautions in this experiment were usually done well. The Hazcard information was often used well, but some candidates gave toxic or hazardous instead of harmful. Precautions such as fume hoods were often correctly stated.

Question 2

It seemed that most candidates took the time to read the opening parts of the question before starting their answer.

(a)   The majority of candidates could correctly calculate a value for M_r. Unfortunately most then gave M_r a unit such as /g whereas M_r has no unit.

(b)   Each column heading needed three things, a description (e.g. H_2O), a quantity (e.g. mol) and an expression to calculate the data (e.g. E/18) as required. Sometimes one of these was missing. Most candidates did calculate the two required mole values.

Also stated was a requirement for a specific number of decimal places and significant figures. There is a general misunderstanding of the meaning of significant figures, decimal places and also trailing zeros. In this case for moles the requirement was for three significant figures in all data. It was pleasant to see that an increasing number of candidates in this examination successfully quoted this data to three significant figures including proper use of trailing zeros e.g. 0.0900. However there were many candidates who did not. For example the second water value of 0.0556 was given as 0.056 or 0.055 or 0.06. There was also some evidence of truncation of data rather than correct rounding. It was not uncommon to see moles values to one significant figure, thus the successive values for moles of $FeSO_4$ of 0.00862, 0.00856 and 0.00915 were given as 0.09, 0.09 and 0.09. The effect of this is to produce a series of two or three values in a vertical line on the plot which makes it difficult for the candidate to achieve a meaningful plot.

Many candidates presented their data in standard form which again is acceptable provided it is done very carefully. For example, all the mole values in the table could be given as 4.61×10^{-3} etc under a column heading of /mol. However, if the values in the table were given as 4.61 etc the column heading needed to be $/10^{-3}$ mol (that is 4.61 millimoles) with the power of 10 associated with the unit not the value. This type of heading is difficult to do correctly. Further these values/units need to be transferred to the graph axes and the slope calculation. It is common to find these factors of 10 missing on axes and in slope calculations. Candidates should be advised to take great care when using standard form.

(c) The question instructed the candidates to put moles of $FeSO_4$ on the *x*-axis and the moles of H_2O on the *y*-axis and the majority did so. Also the candidates were advised not to include an origin. The reason for this was so that the data would scale well over the axes. Those that used an origin often had scales on the *x*-axis that had the data over only four of the available nine large squares which was inadequate. The axes were usually well labelled and most candidates chose reasonable scales that were straightforward to plot and check although some candidates chose awkward scales (e.g. 10 small squares = 0.0078 moles) which makes subsequent work difficult. Some candidates had non-linear scales often at the end of the *x*-axis i.e. … 0.009…0.010 was carried on as 0.02… 0.03 instead of 0.011…0.012 which gave severe misplots in the final five values as well as line difficulties. The plotting of points was mostly well done although the point at 0.0107 was sometimes misplotted at 0.1007. Most candidates drew a reasonable straight line. A few candidates attempted to draw a straight line without using a ruler.

(d) If correctly plotted there were two anomalous points at point 2 and point 10, but if one or two significant figure data was used there were many points away from the line drawn. Very few candidates had two reasonable explanations for their anomalies. Often good reasons were inverted and many were too vague such as 'heated too long'.

(e) The determination of the slope of a straight line requires the co-ordinates of two points that are on the line which should be determined from two sets of construction lines from those points to each axis. The only circumstance where one set of co-ordinates is allowed is where the origin is scaled in and the line goes through it and the origin is quoted. Most candidates had reasonable pairs of constructions and co-ordinates. Some misread scales that were in standard form and others had the *x* and *y* values inverted. A number of candidates attempted unsuccessfully to use the relationship $y = mx + c$ to calculate the slope (*m*). This approach went astray if the candidate took a value for *c* on the *y*-axis when *x* was not zero or a value for *c* on the *x*-axis where the line cut it. The calculation from correct or incorrect data was usually successful unless it was not given to 2 significant figures (excluding trailing zeros), was incorrectly rounded or truncated or had a unit.

(f) The correct response here in terms of data reliability is that the majority of the data points are on the line (or only a very few are not). If the data or plotting was such that there were five or more points off the line then unreliable was accepted if the explanation was correct. Reference to a straight line or passing through the origin relates to the relationship of variables rather than the reliability of data.

(g)

    (i) This required taking the value from **(f)** as a whole number and substituting it for x in the formula, so, for example, a slope of 7.1 would give $FeSO_4.7H_2O$. Some candidates did not take that value but started an empirical formula type calculation instead. Others did not give a chemical formula.

(ii) The question required the slope of the graph to be related to the 7:1 mole ratio of water to iron(II) sulfate. Whilst many candidates were successful here, some gave the ratio but did not relate it to the slope.

CHEMISTRY

| **Paper 9701/52** |
| **Planning, Analysis and Evaluation** |

Key Messages

It is essential that candidates are familiar with the standard experiments included in the syllabus and, if questions are based on these experiments, candidates must not expect to be provided with further details. Where there is limited availability of apparatus it may require the use of class time to explain the procedure that should be used.

If an extended answer is required, guidance will usually be provided as to the points that the Examiner expects to be covered. Candidates should follow this guidance carefully and should make sure that all of the points mentioned have been considered. Extra information should only be included where this is necessary to clarify the answers given.

When plotting graphs, scales that are straightforward to use should be chosen. Using the full extent of a grid that has been provided is important but a plot is acceptable if at least half the grid in both directions has been utilised.

General Comments

It was very apparent in the answers seen that candidates were considerably more comfortable answering questions of a theoretical nature than they were in handling practical details. Candidates' performance on **Question 2** was noticeably higher than that on **Question 1** and, in the latter, it was parts **(a)** and **(b)** where candidates most often obtained credit. **Question 1(c)** assumed that candidates would have an understanding of the correct use of volumetric equipment and an appropriate choice of indicator but this was rarely the case.

Under the pressure of examination conditions it can be tempting to rush to provide an answer before all the requirements of a question have been identified. If specific details are requested, full credit can only be obtained if all of these have been provided. An example was **Question 1(a)(ii)** where the sketch graph needed clear labelling.

A common question expects candidates to state a hazard that may be encountered when performing an experiment and to suggest a precaution that should be taken. Often further information has been provided on the examination paper and, where this is the case, credit available will assume this has been noted. But care is needed: in **Question 1(d)**, for example, some information that was given was not relevant to the concentrations of the reagents being used.

Using a graph to identify anomalies in the data that has been provided is a frequent question. When providing possible explanations for these anomalies, specific issues relating to the procedure being used should be considered. Credit will not be gained for referring to faulty apparatus such as an inaccurate balance or clumsiness when carrying out the experiment.

Comments on Specific Questions

Question 1

(a) Candidates were mostly able to apply Le Chatelier's Principle to the equilibrium and provide an explanation as to why the solubility decreased with increased temperature. The sketch graph in **(ii)** was poorly done largely because candidates did not include all the information requested. The axes needed to be clearly labelled with the correct units and the line should have run from 0 °C to 100 °C passing through the point at 25 °C and 1 g dm^{-3}.

(b) The identification of the independent and the dependent variable was well done and very few errors were seen.

(c) The best answers were achieved by candidates who followed the guidance points **(i)** to **(vii)** in providing their description but others struggled with this question partly through the poor organisation of their answers but often through a lack of clear familiarity with acid-base titrations. A good feature though was the correct use of formulae that led to the majority giving the correct balanced equation of the reaction between calcium hydroxide and hydrochloric acid.

A key point required in the description was the need to use volumetric apparatus such as pipettes, burettes and volumetric flasks where precision was needed. A significant number of candidates used measuring cylinders to measure the volume into a flask before carrying out the titration and an even greater number did not appreciate that similar care needed to be taken when the hydrochloric acid was diluted. The correct dilution of the acid required a calculation of the approximate concentration of the calcium hydroxide. In attempting to do this many revealed confusion between the amount in moles present in the volume taken and its concentration in $mol\,dm^{-3}$.

Although the choice of indicator for the titration was generally identified correctly, many did not provide the colours of the indicator in both alkaline and acid solutions. More were successful in providing details of the calculation based on the volume that was obtained from the titration: a successful approach often involved using sample figures to explain the procedure.

(d) Candidates needed to read the information they had been given carefully; $2\,mol\,dm^{-3}$ hydrochloric acid is an irritant but it is not corrosive as suggested by many candidates. Most appreciated the need for eye protection.

Question 2

(a) Nearly all candidates provided the correct numerical values for the relative formula masses of water and copper sulfate but these values should not have been given units.

(b) There were several steps required to complete the table correctly in this question and many forgot one or more parts of the instructions given. To gain credit a formula had to be provided in the headings of the columns and, for the calculation of the numbers of moles, all the results had to be given to three significant figures. The particular trap that some fell into was to write values such as 0.0400 as 0.04 or 0.040. It was probably easiest to write the answers as a decimal but some chose to write answers such as 0.00890 as 8.90 and change the unit provided in the column heading. If this was done care had to be taken to make sure the units were correct. In the example given, the heading should have been either $CuSO_4 \times 10^3$/mol. or $CuSO_4/10^{-3}$ mol.

(c) Many candidates were able to plot the graph reliably although there were a significant number of mistakes in placing the points correctly. This was not helped if the scale chosen was difficult to interpret.

(d) The anomalous points were usually identified correctly when the graph had been correctly drawn. Where there had been an error in plotting the line, Examiners were usually able to give credit based on what the candidate had done. The reasons given for the anomalies needed to focus on a reasonable problem that might have been encountered when the experiment was done. Candidates needed to think through a likely explanation of the anomaly based on the procedure that was followed. This should not have included clumsiness or faulty equipment. A significant number provided good reasons but associated them with the wrong anomalous point.

(e) The gradient was calculated correctly by most, although candidates could have made this more straightforward by selecting points that corresponded to main divisions on the plotted line. It was acceptable to use points that were calculated for the table in **(b)** but only if the best fit line drawn actually went through these points. Occasionally candidates who had plotted the graph using units such as $/10^{-3}$ mol did not include the 10^{-3} in their calculation.

(f) A comment on reliability should be based on how well points lie on the best-fit line drawn.

(g)   Credit was awarded through reference to the gradient of the line calculated in **(e)**. It was apparent that a few candidates knew that the answer should be $CuSO_4.5H_2O$ and quoted this despite contradictory evidence from their calculation in **(e)**. This was not considered acceptable for the award of credit. In **(ii)** it was sufficient to explain their answer to **(i)** by reference to the gradient obtained.

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Also stated was a requirement for a specific number of decimal places and significant figures. There is a general misunderstanding of the meaning of significant figures, decimal places and also trailing zeros. In this case for moles the requirement was for three significant figures in all data. It was pleasant to see that an increasing number of candidates in this examination successfully quoted this data to three significant figures including proper use of trailing zeros e.g. 0.0900. However there were many candidates who did not. For example the second water value of 0.0556 was given as 0.056 or 0.055 or 0.06. There was also some evidence of truncation of data rather than correct rounding. It was not uncommon to see moles values to one significant figure, thus the successive values for moles of $FeSO_4$ of 0.00862, 0.00856 and 0.00915 were given as 0.09, 0.09 and 0.09. The effect of this is to produce a series of two or three values in a vertical line on the plot which makes it difficult for the candidate to achieve a meaningful plot.

Many candidates presented their data in standard form which again is acceptable provided it is done very carefully. For example, all the mole values in the table could be given as 4.61×10^{-3} etc under a column heading of /mol. However, if the values in the table were given as 4.61 etc the column heading needed to be $/10^{-3}$ mol (that is 4.61 millimoles) with the power of 10 associated with the unit not the value. This type of heading is difficult to do correctly. Further these values/units need to be transferred to the graph axes and the slope calculation. It is common to find these factors of 10 missing on axes and in slope calculations. Candidates should be advised to take great care when using standard form.

(c)   The question instructed the candidates to put moles of $FeSO_4$ on the *x*-axis and the moles of H_2O on the *y*-axis and the majority did so. Also the candidates were advised not to include an origin. The reason for this was so that the data would scale well over the axes. Those that used an origin often had scales on the *x*-axis that had the data over only four of the available nine large squares which was inadequate. The axes were usually well labelled and most candidates chose reasonable scales that were straightforward to plot and check although some candidates chose awkward scales (e.g. 10 small squares = 0.0078 moles) which makes subsequent work difficult. Some candidates had non-linear scales often at the end of the *x*-axis i.e. … 0.009…0.010 was carried on as 0.02… 0.03 instead of 0.011…0.012 which gave severe misplots in the final five values as well as line difficulties. The plotting of points was mostly well done although the point at 0.0107 was sometimes misplotted at 0.1007. Most candidates drew a reasonable straight line. A few candidates attempted to draw a straight line without using a ruler.

(d)   If correctly plotted there were two anomalous points at point 2 and point 10, but if one or two significant figure data was used there were many points away from the line drawn. Very few candidates had two reasonable explanations for their anomalies. Often good reasons were inverted and many were too vague such as 'heated too long'.

(e)   The determination of the slope of a straight line requires the co-ordinates of two points that are on the line which should be determined from two sets of construction lines from those points to each axis. The only circumstance where one set of co-ordinates is allowed is where the origin is scaled in and the line goes through it and the origin is quoted. Most candidates had reasonable pairs of constructions and co-ordinates. Some misread scales that were in standard form and others had the *x* and *y* values inverted. A number of candidates attempted unsuccessfully to use the relationship $y = mx + c$ to calculate the slope (*m*). This approach went astray if the candidate took a value for *c* on the *y*-axis when *x* was not zero or a value for *c* on the *x*-axis where the line cut it. The calculation from correct or incorrect data was usually successful unless it was not given to 2 significant figures (excluding trailing zeros), was incorrectly rounded or truncated or had a unit.

(f)   The correct response here in terms of data reliability is that the majority of the data points are on the line (or only a very few are not). If the data or plotting was such that there were five or more points off the line then unreliable was accepted if the explanation was correct. Reference to a straight line or passing through the origin relates to the relationship of variables rather than the reliability of data.

(g)

(i)   This required taking the value from **(f)** as a whole number and substituting it for x in the formula, so, for example, a slope of 7.1 would give $FeSO_4.7H_2O$. Some candidates did not take that value but started an empirical formula type calculation instead. Others did not give a chemical formula.

(ii) The question required the slope of the graph to be related to the 7:1 mole ratio of water to iron(II) sulfate. Whilst many candidates were successful here, some gave the ratio but did not relate it to the slope.