

CHEMISTRY

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| <p>Paper 9701/12 Multiple Choice</p> |
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| <i>Question Number</i> | <i>Key</i> | <i>Question Number</i> | <i>Key</i> |
|------------------------|------------|------------------------|------------|
| 1 | B | 21 | A |
| 2 | B | 22 | D |
| 3 | A | 23 | A |
| 4 | C | 24 | D |
| 5 | C | 25 | B |
| 6 | C | 26 | C |
| 7 | B | 27 | B |
| 8 | B | 28 | B |
| 9 | C | 29 | D |
| 10 | C | 30 | C |
| 11 | B | 31 | A |
| 12 | D | 32 | D |
| 13 | C | 33 | A |
| 14 | D | 34 | A |
| 15 | D | 35 | D |
| 16 | D | 36 | B |
| 17 | B | 37 | A |
| 18 | A | 38 | B |
| 19 | D | 39 | A |
| 20 | C | 40 | C |

General comments

Questions 1, 3, 5, 7, 11, 13, 19, 21, 23, 25, 27, 32, 33 and 38 were answered well by the majority of candidates. Six questions can be said to have been found to be more demanding. Questions 2, 6, 10, 15, 31 and 39 proved to be more challenging with fewer candidates selecting correct responses.

Comments on specific questions

Question 2

The most commonly chosen incorrect option was **A**. Since the oxygen isotopes present are ^{16}O , ^{17}O , and ^{18}O , there will be O_2^+ ions present with five different masses, which are 32, 33, 34, 35 and 36, meaning the correct answer is **B**.

Question 6

The most commonly chosen incorrect options were **B**, and **D**. The final mixture consists of 3.0 mol of Z and 1.5 mol of unreacted X, this gives a total of 4.5 mol. The temperature of 120°C is 393 K. The volume of 1.0 dm^3 is $1 \times 10^{-3}\text{ m}^3$. If 4.5 mol, 393 K, $1 \times 10^{-3}\text{ m}^3$ and the correct value for R are inserted into $pV=nRT$ then p can be calculated as $1.47 \times 10^7\text{ Pa}$. Therefore, the correct answer is **C**.

Question 10

The most commonly chosen incorrect option was **D**. If the concentration of ethyl ethanoate and the concentration of water, at equilibrium, are both called x , the equilibrium expression becomes $(0.42)^2/x^2 = 0.27$. Solving this gives, $x = 0.81$, meaning option **C** is the correct answer.

Question 15

The most commonly chosen incorrect option was **C**.

With $\text{MgSO}_4(\text{aq})$:

- $\text{HCl}(\text{aq})$ will not give a precipitate.
- $\text{NH}_3(\text{aq})$ will give a precipitate of $\text{Mg}(\text{OH})_2$.
- $(\text{NH}_4)_2\text{CO}_3(\text{aq})$ will give a precipitate of MgCO_3 .
- $\text{Ba}(\text{NO}_3)_2(\text{aq})$ will give a precipitate of BaSO_4 .

The answer is therefore **D**.

Question 31

The most commonly chosen incorrect option was **D**. However, each statement is correct:

- since all molecules have $M_r = 34$, statement **1** is true
- since all molecules have $M_r = 34$, statement **2** is true
- since the equation is $\text{H}_2\text{S} + 3/2 \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{SO}_2$, statement **3** is true.

As statements **1**, **2** and **3** are all true, the correct answer is **A**.

Question 39

The most commonly chosen incorrect option was **D**. However:

- 74.00 g is 1.00 mole of butan-2-ol. 44.64 g is 0.62 mol of butanone.
- 74.00 g is 1.00 mole of butan-1-ol. 54.56 g is 0.62 mol of butanoic acid.
- 74.00 g is 1.00 mole of 2-methylpropan-1-ol. 54.56 g is 0.62 mol of 2-methylpropanoic acid.

Each conversion gives a 62% yield of product. This means that statements **1**, **2** and **3** are all true, so the correct answer is **A**.

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| <p>Paper 9701/22 AS Level Structured Questions</p> |
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Key messages

- When asked to give specific expressions, e.g. concentrations or partial pressures, standard abbreviations are required.
- Use of non-standard abbreviations in explanations e.g. VWFA, should be discouraged unless there is a statement that explains what is meant by the abbreviation used.
- All equations described should be balanced.

General comments

Those responses, which scored highly on this paper, gave specific details relevant to the questions asked and demonstrated excellent knowledge and understanding in both recall and application. Weaker responses tended to show inconsistent levels of knowledge. Generally, weaker answers included an overview of a topic with little attempt to shape the answer to the question.

Comments on specific questions

Question 1

- (a) (i) Clear explanations why methylpropane and butane are a pair of isomers were produced by the majority. Occasionally the incorrect molecular formula of these molecules was described.
- (ii) Correct descriptions of the type of isomerism shown as either structural or chain, were common. There was confusion in some responses, which described the pair of molecules as an incorrect type of structural isomer e.g. position isomers. A very small number of responses incorrectly referred to the isomers as geometric.
- (b) Good responses related the information provided in the question to Le Chatelier's principle and went on to state and explain the effect on the composition of the equilibrium mixture in terms of the exothermic nature of the forward reaction. Weaker answers made no reference to the composition of the mixture.
- (c) (i) Many responses applied knowledge and understanding of the term *dynamic equilibrium* to the graph to show the time at the point when there was no longer a change to the gradient of both curves. A common incorrect answer indicated the time when the concentrations become equal.
- (ii) Most candidates correctly described the amount of methylpropane and butane in the mixture at equilibrium. Incorrect identification of the curves representing the two isomers was the most common mistake.
- (iii) The expression for K_c for this reaction should include the term K_c and the concentrations of the two isomers should be represented using square brackets.

Use of non-standard abbreviations was seen in a small number of responses.

- (iv) The correct calculation of K_c with the correct units was common.

Question 2

- (a) Good responses recalled the correct trend in volatility of the three halogens and explained this trend. There appeared to be some confusion regarding the term volatility, with some stating the wrong trend but producing good explanations for the change in boiling point. Occasional use of non-standard abbreviations to describe the relevant intermolecular force occurred.

Some answers were confused, giving explanations in terms of the differences in bond length and reactivity.

- (b) (i) Despite the question stating that the reaction took place between hydrogen and chlorine at room temperature, some answers stated 'high temperature' was required as the specific condition.
- (ii) Good responses produced a balanced equation representing the reaction with appropriate state symbols and use of \rightleftharpoons to represent the reversible reaction. Identification of iodine as a liquid or hydrogen iodide as a solid, liquid or aqueous were common mistakes. Some equations erroneously showed the reaction of the atoms of hydrogen and iodine.
- (c) (i) The definition of a Brønsted-Lowry acid was well known.
- (ii) Correct identification of the acid reactant HCl was seen frequently. However, there was confusion with the term *conjugate base*, many responses describing H_3O^+ as the conjugate base of HCl .
- (iii) A significant proportion of answers identified the bond formed between the hydrogen cation and water as a dative covalent bond or co-ordinate bond. Some incorrectly stated that the bond formed was a hydrogen bond.
- (iv) This question proved challenging for many. Excellent responses appreciated that the H_3O^+ ion contains three bond pairs and one lone pair of electrons and correctly deduced the shape and H-O-H bond angle in the H_3O^+ .

Question 3

- (a) (i) The equation for the reaction of silicon tetrachloride, including state symbols, presented numerous difficulties. Many candidates stated the correct formulae for reactants and products but failed to correctly balance the equation. State symbols were omitted by some, and where used, the correct state of silicon tetrachloride was rarely seen.
- (ii) A relatively small number of responses correctly described the reaction of silicon tetrachloride with water as a hydrolysis reaction. Hydration, redox and neutralisation reactions were common incorrect responses. Reference to an exothermic reaction was described by some, even though the question stated 'Ignore the endothermic/exothermic nature of the reaction'.
- (iii) Correct bonding of the two compounds was seen frequently. Reference to intermolecular forces present in sodium chloride or giant covalent structure of silicon tetrachloride were seen in weaker responses.
- (iv) This proved challenging for many. Excellent responses were seen by those who explained the difference in bonding in terms of the difference in electronegativity between the atoms of sodium and chlorine in NaCl and silicon and chlorine in SiCl_4 , resulting in complete transfer of electrons or shared pairs of electrons.

A relatively small number of answers referred to the electronegativity of the molecules or ions rather than the atoms.

Confusion was seen in some responses, which argued that the number of bonds present in a formula unit/molecule determined its electronegativity or that the difference in bonding arose because of the effect of different shaped molecules on polar bonds.

Some answers made no attempt to answer the question but described the meaning of the term *electronegativity* and stated the bonding present in the two different species.

- (b) (i) The correct identification of the oxidation number of chlorine was described in the majority of answers.
- (ii) Many responses correctly identified the type of reaction occurring as disproportionation; a relatively small number of answers spelled the term correctly.
- (iii) The majority of answers appreciated that the chlorine is added to water to kill micro-organisms. Some excellent responses gave details of how the micro-organisms were killed in terms of the active species involved.
- (c) Many equations correctly identified NaClO as one of the products of the reaction. A significant number of responses combined the reaction of NaOH with HCl and HClO . Often equations were not correctly balanced.

Question 4

- (a) The use of crude oil as a source of hydrocarbons was commonly seen. However, there were incorrect references to fruits as the source. Detailed descriptions of the fractional distillation process were seen in good answers; others simply stated the name of the process.
- (b) (i) The correct identification of the process was common.
- (ii) Representation of the formulae of hexane, butane and ethene were well known and many equations showed these correctly as the products in the equation. Not all equations were balanced.
- (c) The correct calculation of the volume of carbon dioxide produced was commonly seen. Occasionally, answers calculated the molecular mass of ethene incorrectly or did not use the correct stoichiometry. Some candidates did not use the idea that 1 mole of gas occupied 24.0 dm^3 volume at room temperature and pressure and used the ideal gas equation instead.
- (d) (i) The meaning of the term *free radical* as a species containing an unpaired electron was rarely seen. Frequent misconceptions included 'containing a single electron', 'free electrons', 'a lone pair of electrons' or 'it is an unpaired electron'.
- (ii) Correct identification of the type of bond breaking was common but was not always spelled correctly. A smaller number of responses clearly explained the process in terms of each of the products keeping one of the bonded pair of electrons.
- (iii) Correct identification of the stage of the reaction mechanism was common; correct spelling of the term *propagation* was rare. Incorrect answers included identification as initiation, termination, step 3, or as free radical substitution.
- (iv) For many, this equation proved straightforward. Incorrect responses included products of hydrogen free radicals and chloromethane or the production of positively charged ions.
- (v) This question proved challenging. Some excellent answers described the presence of sigma and pi-bonds in alkenes compared to only sigma bonds in alkanes and described the pi-bond as key to the reaction of alkenes with electrophiles. Some referred to the $\text{C}=\text{C}$ of alkenes as the pi-bond rather than a sigma bond and a pi-bond. Many responses were not specific to sigma and pi-bonds, with explanations given in terms of the region of high electron density in $\text{C}=\text{C}$.

Question 5

- (a) (i) Naming ester **V** presented difficulties for many. Ethyl propanoate and propyl methanoate were common incorrect answers.
- (ii) Identification of an alkali, like aqueous NaOH , to form the salt of the carboxylic acid and alcohol was not well known. Addition of aqueous HCl was a common incorrect response.
- (iii) In a small number of answers, an incorrect alcohol was identified as the product. Many answers realised that propan-1-ol is produced but did not show the full displayed formulae; omission of the O-H bond was common. Occasionally, skeletal formulae was incorrectly used to draw the structure.

- (iv) Many uses for ester **V** were seen. Solvents and perfumes were the most common responses.
- (b) (i) The majority of responses worked out the correct empirical formula of **W** using the % composition of the elements present. Common mistakes involved finding the smallest whole number ratio of the % values with no use of relative atomic mass, calculating relative atomic mass/percentage mass in the first step of the reaction and incorrect rounding of values to find the whole number ratios.
- (ii) Good responses stated that the molecular mass of **W** is required to find its molecular formula.
- (c) (i) Interpretation of the skeletal formula of the compounds to deduce the common molecular formula was generally well done. Some answers reflected difficulties interpreting the skeletal formulae and gave incorrect numbers of carbon and hydrogen atoms.
- There was occasional misunderstanding of the term *molecular formula*, either showing three different structural formulae or descriptions of the different functional groups present.
- (ii) Many appreciated that **X** and **Z** contained the same functional group, therefore the observation in **X** was mirrored with that of **Z**. A relatively common misconception was that esters react with sodium. When the carboxylic acid, **Y**, was added to sodium, effervescence was often described but the formation of a precipitate was a common incorrect response.
- (d) This equation proved demanding. Many attempts showed carbon dioxide and water as products of the reaction. The formula for sodium carbonate was not well known and was seen frequently as NaCO_3 . Many answers described the reaction of ethanoic acid rather than methanoic acid. Even when the correct species were described in the equation it was not always balanced.

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| <p>Paper 9701/33 Advanced Practical Skills 1</p> |
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Key messages

- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data.
- Candidates should ensure they use a sharpened pencil to plot points and draw lines of best fit in questions involving graphs.
- Candidates should ensure their data reflects the precision of the apparatus used.
- It is essential that candidates enter the information regarding session and laboratory on the front cover of the paper so that results can be matched with the supervisor values that are relevant to that session/lab.

General comments

This was a paper that tested across a wide range of practical skills. Candidates need to take time to study the instructions more closely both in terms of the practical method and in terms of further information provided in the questions. There were many examples of where candidates did not quote the time to the nearest second in **1(a)** or suggested the concentration had changed in **2(d)**.

Most centres correctly included the supervisor script(s) and report(s) but it is a matter of concern that some centres, and some hosting venues, only sent one supervisor's script purportedly covering multiple sessions and laboratories. This is only acceptable where the concentrations of solutions issued to candidates are all the same.

Comments on specific questions

Question 1

Almost all candidates completed the practical tasks, usually to a high standard. However, many candidates found the remainder of the question more demanding.

- (a) I** Almost all candidates gained the mark for drawing a suitable table for their results. Some candidates split their tables between pages 3 and 4 which occasionally led to omissions in the data required. When 'a table' is specified it should normally involve no repeat of headings.
- II** This was well answered. The most frequent error was to omit, or give an incorrect unit for, rate.
- III** This mark was more commonly lost. Candidates were using burettes to measure the volumes of **FA 1** and water so should have recorded these to .00 (or to .05 if they overshoot when delivering a volume). Many ignored the instruction to record the time taken as an integer and others should be reminded that, for example, 33.0 is not an integer.
- IV and V** were gained by most candidates with the selection of either 25.00, 30.00 and 35.00 cm³ or 30.00, 35.00 and 40.00 cm³ of **FA 1** being common.
- VI** Most candidates gained the accuracy mark for the correct trend of times with volumes of **FA1**. A few candidates would have benefited from repeating one of the experiments so that all their times decreased as volume of **FA1** increased.

- VII** and **VIII** The scoring of these accuracy marks tended to be centre-specific. This indicates that some candidates have enjoyed greater exposure to this type of practical exercise than others.
- IX** The most common error in calculating the rate was one of rounding. Candidates should be reminded that, for example, $500 \div 33 = 15.1515$ would be 15.2 when rounded to 3 significant figures.
- (b) I** Almost all candidates assigned the correct variable to each axis and gained this mark.
- II** The majority correctly selected scales that led to plotted points covering more than half the available length on the two axes. Candidates should be encouraged to use simple scales such as 1, 2, 4 or 5 units to a 20 mm square wherever possible.
- III** A poor choice of scale usually led to errors in plotting. Some candidates were too imprecise for this mark to be awarded. Candidates should be reminded to use a sharp pencil and ensure any point that should be on a line is on that line and points within a square should be plotted in the correct portion of the square.
- IV** Lines of best fit may be straight or a smooth curve, but it is important in either case that anomalous points are clearly indicated. Candidates should either ring points they consider anomalous or otherwise label them. Many candidates simply joined the points for the first and second experiments without ensuring the other points were balanced on either side of the line.
- (c)** This mark was gained by a minority of candidates. Many candidates appeared to ignore their graphs, as a common response was that the rate was directly proportional to the concentration of **FA1** when there was no extrapolation of the line to the origin. The other common error was that rate increased as concentration increased without mention of 'proportional'.
- (d)** The first mark for use of the time for the second experiment and 2 s was commonly awarded. However, some candidates subtracted 2 instead of adding it. Hence, the rate calculated was greater than the minimum rate in their table in **(a)** or plotted in **(b)** thus not answering the question.
- (e) (i)** This question was challenging for candidates although a number correctly stated that less depth of solution would lead to a longer time for the print to be obscured. Many stated that, as the concentration was unchanged, the time would be unchanged without considering the dimensions of the beaker and its effect on the same total volume of reactants. Others linked an 'increase in surface area' (not appropriate) with a 'decrease in time taken' (incorrect).
- (ii)** Many candidates gave incomplete responses to this question as they simply stated that the rate would be 'very slow' because of the low concentration. This disregarded the '*never became invisible*' in the question. One misconception frequently seen was that the solution was too dilute for any reaction to occur. However, a small number of candidates gave excellent answers indicating they fully understood the experiment they had carried out.

Question 2

Candidates generally found this question the most demanding even though it involves one of the quantitative techniques specified in the syllabus.

- (a) I** Although most candidates recorded the required data some wrote 'weight' instead of 'mass' or wrote the unit for temperature as C° so could not access the mark.
- II** Almost all candidates gave their balance readings to the same number of decimal places but many did not record thermometer readings to .0 or .5°C. It is important to indicate the precision of the apparatus used when recording experimental data.
- III** and **IV** Many candidates gained both marks for accuracy when comparing values of $\Delta T/m$. This was even true of some candidates who did not appear to add all the **FA 3** to the water as the mass of **FA3** recorded was considerably lower than the approximately 4 g supplied.
- (b) (i)** A significant number of candidates only quoted their answer to 2 s.f. even though the balance readings were to 2 d.p. so could not access the mark. Candidates should be reminded to read and

employ the Quantitative Analysis instructions given at the start of the paper. Some candidates did not use the A_r values given in the Periodic Table. At AS and A Level it is expected that values correct to 1 d.p. will be used.

- (ii) The most common error was to use the mass of **FA3** rather than the volume of solution (25 cm^3) in the 'mc ΔT ' calculation thus ignoring the information given below the stem of the question.
- (iii) Candidates found this mark least accessible of the three available. While many calculated (ii) \div (i) successfully the conversion from J to kJ was not always matched by the units given. Only a minority gave the expected kJ mol^{-1} or J mol^{-1} . Although all candidates recorded a decrease in temperature in (a) some indicated the reaction was exothermic as a negative sign was given.
- (c) Many answers lacked clarity with candidates suggesting, for example, using an 'accurate thermometer' without stating that it should have smaller scale divisions. A digital thermometer is not necessarily more accurate so could not be awarded the marking point. Many candidates suggested using a lid or extra lagging for the cup to prevent heat loss even though they had recorded data in (a) indicating an endothermic reaction. Of those who correctly suggested using a greater mass of **FA3** some went on to also suggest using more water so were unable to access the marking point.
- (d) This was possibly the most demanding question on the paper. Relatively few candidates acted on the information given that the concentration was correct. Most referred to the water of crystallisation diluting the solution and relating lower concentration to greater time for the 'disappearing print' reaction. Candidates were required to use the fact that the reaction in **Question 2** was endothermic and relate this to the method in **Question 1**.

Question 3

This question discriminated well. Many higher scoring candidates achieved double figures, but a similar proportion of candidates scored poorly on tests that should have been relatively straightforward for those with experience of them.

- (a) (i) Almost all candidates noted effervescence but far fewer tested the gas evolved. Candidates should be aware that vigorous effervescence occurs in a small number of reactions:
- acid + metal
 - acid + carbonate
 - H_2O_2 + suitable catalyst.

Candidates should be reminded that 'gas produced' is not an observation: it is a conclusion. Of those candidates testing the gas with limewater some reported the limewater turning cloudy instead of cloudy white or white precipitate. 'Cloudy' is not a colour but indicates the previously transparent contents of the test-tube are now opaque.

- (ii) Almost all candidates selected a named soluble barium salt as a reagent with many also selecting an acid. Those who selected nitric acid or hydrochloric acid usually gained both marks. However, a sizable number of candidates selected sulfuric acid so could access neither mark. Some candidates suggested using the barium salt solution in excess, which also could not be credited.
- (iii) Identifying the cation proved difficult for many, but around half the candidates gained this mark. The most commonly seen incorrect responses were $(\text{NH}_4)_2\text{SO}_4$ and, even though the question asked for the formula of **FA4**, SO_4^{2-} .

- (b)(i)** Most candidates gained the mark for the colour change on heating solid **FA5** though some did not as they described the solid left as '*precipitate*'. Far fewer noted the formation of condensation on initial gentle heating.

It was apparent that some candidates did not read the instructions and added the residue on heating **FA5** to the acid rather than the rest of the sample. Although many noted effervescence fewer noted the colour of the solution.

If marks were not awarded for the tests with the alkalis it was usually for lack of precision, for example, '*turns dark blue*' without mention of state or use of excess aqueous ammonia.

- (ii)** Many incorrect responses were seen such as '*combustion*' and '*redox*'. Few candidates realised that, as heating was required for **FA5** to decompose, '*thermal*' had to be part of the answer.
- (iii)** Almost all candidates identified the cation as Cu^{2+} with many also correctly identifying CO_3^{2-} . Some candidates gave OH^- as the anion but this could only be credited if there was some evidence of condensation in **(b)(i)**. Also, some candidates selected NO_3^- as the anion without any evidence.

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| <p>Paper 9701/34 Advanced Practical Skills 2</p> |
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Key messages

- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data.
- Candidates should ensure they use a sharpened pencil to plot points and draw lines of best fit in questions involving graphs.
- Candidates should ensure their data reflects the precision of the apparatus used.
- It is essential that candidates enter the information regarding session and laboratory on the front cover of the paper so that results can be matched with the supervisor values that are relevant to that session/lab.

General comments

Candidates need to take time to study the instructions more closely both in terms of the practical method and in terms of further information provided in the questions. Examples of where this was evident were the number of candidates who did not record burette readings for the rough titre in **1(a)** or who suggested tests for anions in **3(b)(i)**.

Most centres correctly included the supervisor script(s) and report(s) but it is a matter of concern that some centres, and some hosting venues, only sent one supervisor's script purportedly covering multiple sessions and laboratories. This is only acceptable where the concentrations of solution issued to candidates are all the same.

Comments on specific questions

Question 1

There were many good marks achieved for this familiar technique and type of calculation. Marks tended to be centre-dependent indicating that some candidates have less exposure to practical skills at this level than others.

- (a)** Most candidates gained most, if not all, of the marks in this section. However, several common errors were evident:
- burette readings not recorded for the rough titre
 - burette readings recorded to 1 d.p. for the accurate titres
 - performing a third accurate titration when the first two titres were within 0.10 cm^3 .

Often in the last case the third titre value was outside the range allowed from either of the previous titres so the mark could not be awarded.

Almost all candidates gained at least one mark for accuracy.

- (b)** Most candidates gained the mark for the mean with very few rounding errors or incorrect selection of titres seen.
- (c)(i)** While most candidates gave their answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the expected 3 or 4 significant figures some then gave the answer to **(c)(v)** to 2 s.f. so could not access the mark.

- (ii) Many excellent answers were seen with only a small number of candidates mistakenly using 25.0 cm^3 instead of their value for **(b)** or omitting the use of 1000.
- (iii) The mark for using the mole ratio from the equation was awarded to most candidates.
- (iv) A large majority of candidates gained this mark. The errors were usually either using the M_r of FeSO_4 or not using the A_r value for Fe given in the Periodic Table. At AS and A Level it is expected that values correct to 1 d.p. will be used.
- (v) The most common error was to omit the factor of 40. Candidates should be reminded to read the questions carefully as the answer to **(c)(iv)** concerned 25.0 cm^3 of **FB2** whereas the mass given in the identity of **FB2** on page 2 was for 1 dm^3 of solution.
- (d) Correct answers to this section were rare: most candidates stated the student was correct, despite the reaction of $\text{FeSO}_4(\text{aq})$ and $\text{NaOH}(\text{aq})$ featuring later in the paper. Some candidates stated the student was incorrect but did not give a correct reason. One common example was that there would be no colour change at the end point for the reaction between sulfuric acid and aqueous sodium hydroxide.

Question 2

Candidates generally found this question the most demanding even though it involves one of the quantitative techniques specified in the syllabus.

- (a) Candidates should be reminded to record their data to reflect the precision of the apparatus used. Many were unable to access the first mark as their thermometer readings were given as integers. As the thermometers specified in the Confidential Instructions are graduated at 1°C the readings should all have been to .0 or .5 $^\circ\text{C}$. Some candidates were disadvantaged because at least one centre provided them with thermometers calibrated at .5 $^\circ\text{C}$ so tended to give their readings to .1 $^\circ\text{C}$, which was not acceptable. Using burettes to measure the volumes of **FB4** meant volumes should have been recorded to .00 cm^3 (or to .05 if candidates overshoot when delivering a volume). Some candidates ignored the prompt given in the method.

Most candidates were in good agreement with each other and in agreement with their supervisor so gained at least one of the marks for accuracy.

- (b) Few candidates gained all four marks for this section. Common errors included:

- extending the y-axis to 0°C
- failure to include the extra 2°C above the highest temperature reached in **(a)**
- inaccurate plotting of points even though they were usually on the grid lines
- use of a blunt pencil
- failure to label points as anomalous even when they were distant from the lines of best fit.

Candidates should be reminded that lines of best fit may be smooth curves as these would have been more appropriate for the part of the graph showing an increase in temperature in many cases. More candidates gained the fourth mark as they were able to read the intersect to 0.2 cm^3 accuracy. However, some candidates gave an integer answer or gave the temperature at the intersect instead of the volume so were unable to access the mark.

- (c) (i) Most gained this mark: errors were rounding the answer to 1 s.f. or using 10.0 cm^3 as the volume of **FB3** instead of their answer to **(b)**.
- (ii) This part was also generally well answered and the mark was often awarded. However, some candidates multiplied their answer to **(i)** by 2 instead of dividing or divided this or the correct answer by 100 instead of multiplying.

- (d) Most included the use of $(Q =) mc\Delta T$ in their answer so gained at least one mark. There were various attempts at explaining 'm' and ' ΔT ' but they often lacked the appropriate detail required to secure the mark. Careful reading of the question may have benefited some candidates as dividing Q by moles of water formed or by moles of sodium hydroxide were nearly as common as the correct use of moles of sulfuric acid or the answer to (c)(ii).

Question 3

Candidates should consider the purpose of a test and what they might be expected to observe. In this way more precise observations might be supplied. However, some candidates appeared well-prepared and gained good marks.

- (a) Candidates should be reminded to follow instructions and not to use additional reagents. If there is no visible reaction then that or '*no change*' is a suitable observation: leaving the box blank, a dash, and '*no observation*' are not.

The test with aqueous acidified potassium manganate(VII) proved to be the most difficult. This reagent is used to indicate whether the 'unknown' can be oxidised which is shown by the colour change (or lack of change) of the reagent. A significant minority of candidates left the 'warming' box blank for **FB6** possibly as there was no change. However, many correctly noted the decolourisation for the **FB5** mix on heating. '*Colourless solution*' is insufficient as an observation: the solution either '*turns colourless*' or '*stays/remains colourless*'.

When dilute nitric acid was added to the 'unknowns' most candidates correctly observed there was 'no visible reaction' or 'no change'. However, some mistakenly wrote '*no ppt*'. As a precipitate of a nitrate is not encountered at AS and A Level this was not an acceptable response. This is an example of candidates not thinking about the possible outcomes of tests before carrying them out.

Most candidates gained the marking points for the tests with aqueous silver nitrate although some negated the mark by adding aqueous ammonia (an extra test) to any precipitate.

The tests with dilute hydrochloric acid and aqueous barium chloride (or nitrate) were well executed. However, with this test and with Ag^+ (aq) some candidates reported '*milky solution*' or '*white solution*' where '*white ppt*' was the expected observation: a solution cannot involve a precipitate.

While the marking point for **FB5 + FB6** was gained by many, fewer candidates gained that for **FB5 + FB7** as they reported a precipitate.

A few candidates did not use fresh samples of solution for each test. For example, on adding Ag^+ (aq) to **FB6** a pink precipitate was reported by some.

- (b) (i) Many candidates answered this part well with full marks being awarded to a substantial minority. The most common reasons for marks to be withheld were not adding excess alkali and not reporting the precipitates with **FB7** turning brown in air. A few candidates correctly used a named sulfate to distinguish between Ca^{2+} and Ba^{2+} in **FB6** showing a good understanding of the task.

Although almost all candidates correctly selected NaOH (aq) and NH_3 (aq) as reagents some also selected BaCl_2 , AgNO_3 , limewater and/or heating with Al foil + NaOH (aq) thus ignoring that only tests for cations were required.

- (ii) Most candidates gained at least one mark out of the two. The incorrect ions most commonly seen were Mg^{2+} , Cr^{3+} and Br^- . A few candidates ignored the instruction to give the formulae of the ions and wrote names, a small number of candidates confused cations with anions.
- (iii) A minority of candidates gained this mark and many candidates left the line blank. The equation attempted more widely was for the precipitation of BaSO_4 , some candidates omitted state symbols. Candidates that wrote the equation for producing $\text{Fe}(\text{OH})_2$ often failed to balance the equation: some also omitted state symbols contrary to the instructions. Candidates from some centres were more proficient than others, indicating a greater exposure to the task.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out and never overwritten with the new answer.

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 had prepared well for the examination were able to attempt all the questions. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

- (a) (i) Most candidates answered this well. Common errors were $3s^23p^63d^{10}4s^1$ and $3s^23p^63d^74s^2$.
- (ii) This was well known. $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ being pink and CuCl_4^{2-} green were common errors.
- (iii) Many candidates described why complexes are coloured instead of why metal ions with different ligands can have different colours.
- (b) This proved difficult for some candidates. Some candidates stated that they have a full d-orbital instead of every d-orbital is full. A number of candidates stated that no d-d splitting occurs rather than no d-d transition can occur.
- (c) (i) Most candidates gave the correct answer.
- (ii) This proved challenging for many candidates and answers often lacked clarity or used Le Chatelier's principle in their explanation. Only a small number of candidates gave a suitable explanation. Common errors included just comparing the two equilibrium constants or stating that $[\text{Ag}^+]$ would increase.
- (iii) This question was usually fully credited.
- (iv) Common incorrect answers seen were $K_{\text{stab}}/K_{\text{sp}}$ and $K_{\text{sp}}/K_{\text{stab}}$.
- (d) This was well known.
- (e) (i) Many fully correct answers were seen. The most common omissions were the label for the platinum electrode and pressure (1 atm) for hydrogen gas, also a small number did not have their salt bridge immersed in the two solutions.
- (ii) This was generally well answered.

Question 2

- (a) A common error was forming CO_2 and $\frac{1}{2}\text{O}_2$ as products.
- (b) The trend and its explanation were well understood by candidates.
- (c) Many candidates correctly quoted the ionic radii for these cations and the trend. Common errors were quoting atomic radii or atomic number or giving the reverse stability trend.
- (d) Many candidates answered this well, gaining full credit. Some thought dolomite was pure $\text{CaMg}(\text{CO}_3)_2$ and just calculated the moles of dolomite without any reasoning, which gained no credit.

Question 3

- (a) Most candidates gave a correct answer.
- (b) (i) Many candidates understood the idea of a transition element but some definitions often lacked precision. A common example of imprecision in candidate's definitions was stating that a transition element 'is an element with an incomplete d sub-shell and forms one or more ions'.
(ii) Most candidates answered this question correctly.
- (c) Most candidates gave the correct formulae of the two oxides, but often omitted the oxidation number for each iron.
- (d) This was generally well answered. Common errors were incorrect use of brackets, for example $[\text{Ni}(\text{CO}_4)]$, and 2- charge for the nickel complex.
- (e) (i) Most candidates recognised geometrical isomerism. However, candidates stating optical isomerism for this question was a common error.
(ii) Many fully correct answers were seen. Common errors were due to use of incorrect formulae for ligands: O_2H and Cl_2 .
- (f) (i) This was often answered well. Common errors included putting ionic charges outside the final set of square brackets, e.g. $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ or $K_{\text{stab}} = \frac{[[\text{Cu}(\text{H}_2\text{O})_4(\text{NH}_3)_2]^{2+}][[\text{Cu}(\text{H}_2\text{O})_6]^{2+}][\text{NH}_3]^2}{[\text{Cu}(\text{H}_2\text{O})_6]^{2+}[\text{NH}_3]^2}$. The units were usually correct.
(ii) Most candidates found this challenging. Some very good answers were seen, although many candidates did not answer in terms of moles of species on the reactant side and product side.
(iii) Most candidates gave a correct answer.

Question 4

- (a) Many fully correct answers were seen.
- (b) (i) Many candidates gave the correct answer. A common error was omitting s^{-1} in the units.
(ii) This was not well known. Many thought the rate constant was independent of temperature.
- (c) Some answers lacked sufficient detail, for example when to draw a tangent to the curve (time = 0 sec). Weaker responses described how to calculate a half-life to determine the order.
- (d) This was generally well answered. Many incorrect answers resembled graphs associated with investigating rates of reaction.
- (e) (i) Most candidates gave a correct answer.
(ii) This was often answered well. Common errors included unbalanced equations and candidates omitting the catalyst was regenerated in step 3.

Question 5

- (a) This was not well known. Many candidates thought enthalpy of neutralisation could be either exothermic or endothermic.
- (b) Many candidates gave a correct answer. Common errors were omitting 'dissolving in water' or stating that the solute was 'dissolving in a solution'.
- (c) This question discriminated well. Many correct answers were seen. Common errors were incorrect signs in their calculation, not multiplying 251 by 3 or including additional data such as the first ionisation energy of K.
- (d) Many candidates gained credit, although a significant number did not link the difference in ionic radii to the strength of the attraction between ions.
- (e) (i) Most candidates gave a correct equation.
(ii) This was generally well answered.

Question 6

- (a) Most candidates stated benzene had a planar structure with a bond angle of 120° or the carbon atoms were sp^2 hybridised. However, many answers lacked sufficient detail and did not refer to how the sigma and pi-bonds are formed. Some did not state that the electrons in the pi-bonds were delocalised and a number described the Kekule structure of benzene (alternating single and double carbon to carbon bonds).
- (b) (i) This was usually well known. A common error was omitting a charge in one of the products.
(ii) Some very good answers were seen. The intermediate was normally awarded. However, many candidates did not draw curly arrows with enough precision and H^+ was normally omitted as a final product.
(iii) This question was usually fully credited.
(iv) Many candidates stated the type of reaction was reduction. A common error was the omission of 'concentrated' with hydrochloric acid.
- (c) (i) Many correct answers were seen. Common errors were $C_{15}H_{15}N$ and $C_{15}H_{15}O_2$.
(ii) This was generally well answered. Common errors were carboxyl and amide.
(iii) This calculation was done well by many. A common error was over rounding during the calculation.
- (d) Most candidates found this challenging. Many candidates recognised the methyl group was an electron donating group, although only a few discussed the subsequent stability of the two carbocations.

Question 7

- (a) (i) Most candidates gave a correct answer.
(ii) This proved difficult for many candidates. Some incorrectly predicted R_f values would decrease/not change. Those that did correctly predict an increase often did not sufficiently explain the increase in solubility using a more polar solvent.
- (b) (i) This was generally well answered. Common errors were unbalanced charges in their equations, forming the acyl chloride and the omission of water.
(ii) Most candidates gave the correct structure of the zwitterion. A common error was suggesting that water provided the H^+ ion to protonate the NH_2 group and OH^- ion to deprotonate the CO_2H group.

- (c) Most candidates gave a correct answer.
- (d) (i) Most candidates correctly identified the mechanism, although many omitted the need for pressure.
- (ii) Many candidates gave the correct trend and linked this to the electronegativity of the chlorine atoms. However, only a small number explained that the O-H bond would be weakened and become easier to ionise.
- (e) Most candidates were able to identify one or two of the isomers – normally as the dipeptides. The ester was least commonly awarded.

Question 8

- (a) Many candidates answered this well. Common errors were omitting 'di' or not numbering correctly.
- (b) (i) This was usually well known. Common errors were four peaks in carbon-13 and two peaks in the proton NMR.
- (ii) This was generally well answered and the OH proton identified. Many answers lacked clarity and referred to compounds just reacting with D₂O.
- (c) Some very good answers were seen. Most candidates correctly identified the product from the reaction with Na and Br₂. The other reactions were less well known. Common errors included:
- the Friedel-Crafts ring substituted product with CH₃COCl
 - the substitution of the OH in the ring with Br for the reaction with Br₂
 - the substitution of the OH or Cl in the ring with -N=N-C₆H₅ for the reaction with benzene diazonium chloride
 - the retaining the N≡N in the substituted product with benzene diazonium chloride.

The type of reaction was less well known. The most common errors were 'acid-base' for the reaction with Na and 'diazotisation' for the reaction with benzene diazonium chloride.

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| <p>Paper 9701/52 Planning, Analysis and Evaluation</p> |
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Key messages

- Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates could not provide suitable details of apparatus needed in **Question 1(a)(iii)** and the required measurements in **Question 1(e)(ii)** were not known.
- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures.
- Candidates should be dissuaded from offering lists of answers beyond the number of responses asked for. **Question 2(d)(iii)** required one piece of apparatus and correct answers were often contradicted by inclusion of other, unsuitable, pieces of apparatus.
- Candidates should be aware that lines of best fit need to split the plotted points in such a way as to have an approximately equal number of points (excluding anomalies) either side of the line. Drawing a line from the origin to the last point may not necessarily result in this outcome.

General comments

Both questions had multi-step calculations. It is important that candidates do not round in early steps and do their rounding to the required number of significant figures after calculating the final answer.

Question 2 involved graph work. Candidates are advised to clearly show their points by using a diagonal cross, 'x', with the intersect of the lines being the exact co-ordinates on the grid. Alternatively, a point within a circle, ⊙, would be suitable with the point being the exact co-ordinates on the grid. Candidates should be aware that a single point (with no circle) will likely not show up if a line of best fit needs to be drawn over it.

Comments on specific questions

Question 1

- (a) (i) The opening question was well answered but poor examination technique was evident, especially for the dependent variable. Most realised that it was the *volume* of gas/carbon dioxide, but often said 'amount of gas' or even simply 'carbon dioxide', neither of which was enough to be awarded credit. The independent variable was the type of metal ore, although this could be expressed in a variety of ways. However, the mass of the metal ore was not the independent variable.
- (ii) Many candidates opted to keep the concentration (or even volume) of the acid constant, presumably on the false premise that this was a rate of reaction investigation. Very few realised that the temperature of the collected carbon dioxide needed to be kept constant. Others opted for temperature of the reaction mixture (based upon the idea of a rate experiment).

(iii) It is apparent that many candidates were unfamiliar with basic practical apparatus.

Candidates were faced with three problems.

- The first problem was to enable mixing of ore and acid without loss of gas. Better responses used the idea of a small vessel containing ore suspended by string within a sealed flask containing acid. Divided flasks were also seen in responses. In most incorrect responses, candidates simply had the acid and carbonate reacting in a flask, and in the absence of other details, it was therefore assumed that the first few bubbles of carbon dioxide would escape to the atmosphere.
- The final problem was collection over water. Most of the candidates opted for an inverted measuring cylinder, but an inverted burette would have been acceptable. However, a large proportion of candidates did not appreciate that collection over water was required and opted for a gas syringe, sometimes connected the syringe after the gas was bubbled through water.
- The intermediate problem was to get the gas from the reaction vessel into a collection vessel in sealed apparatus. This was by far the easiest step. Inaccurate diagrams were often seen, with delivery tubes entering through the side of measuring cylinders were not accepted.

(b) It was expected that candidates would realise that some carbon dioxide would dissolve if collected over water and that the solution would be to use a gas syringe instead of an inverted measuring cylinder.

(c) (i) Better performing candidates realised that each experiment was repeated to ensure reliability or to allow the identification and removal of anomalous results. Some candidates clearly had not fully read the question and answered that it was to calculate an average (which was given in the question) or to make the results 'more accurate'.

(ii) Better performing candidates identified the anomalous result (Expt 2 in siderite) and went on to calculate a correct average.

(d) This was a difficult question, but it produced some very good answers, usually as a result of candidates realising that hydroxides might also be present and react with the acid.

(e) (i) Most candidates completed the calculation correctly and gained full credit. The most common error was to ignore the instruction to give the answer to three significant figures.

(ii) The lack of practical experience involving gravimetric techniques of many candidates was evident, as only a few realised that as well as recording the mass of crucible and ore sample before and after heating, it was essential to find the mass of the crucible without anything in it.

(iii) The idea that heating to constant mass was needed for accuracy was well known.

Question 2

(a) Most candidates deduced the correct ionic equation from the electrode potentials given in the question, although a few were left unbalanced.

(b) Percentage error is a concept not fully appreciated by many of the candidates. About half correctly calculated the percentage error, with most other answers being either double or half the correct value.

(c) The idea that gloves should be worn was almost universally known.

(d) (i) This calculation was very well answered, with nearly all candidates getting the answer of 15.0 or 15. The latter answer was not given to the required number of significant figures, showing poor examination technique.

(ii) Approximately half the candidates completed the table correctly; the vast majority gave the numbers to two decimal places.

(iii) Most suggested correctly a burette was a suitable piece of apparatus. Incorrect responses included pipette, measuring cylinders, gas syringes and beakers.

- (e) (i)** The points were plotted correctly by most candidates. A minority omitted the plot at the origin. Many good ruler lines of best fit were drawn.
- (ii)** The relationship of direct proportionality was identified by nearly all candidates.
- (f) (i)** Nearly all candidates were able to take a value from the graph correctly, although the different scales on each axis meant 0.18 was given instead of 0.19.
- (ii)** The final calculation was more challenging than the previous ones, but most candidates still achieved full credit. Common errors included opting for an incorrect volume of copper solution or rounding too soon in the calculation.