

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

The majority of candidates were able to finish the paper within the hour allowed.

Candidates found **Questions 3, 4, 5, 6, 9, 10, 13, 15, 16, 18, 21, 24, 28** and **37** relatively easy. **Questions 2, 11, 20, 29, 32** and **38** were found to be more challenging.

Question 2

The most commonly chosen incorrect answer was option **C**. To produce 800 cm³ of 0.100 mol dm⁻³ solution requires 0.08 moles of the specified substance. Since the *M_r* of (NH₄)₂CO₃·H₂O is 114, this appears to be 9.12 g. However, the question says the solution must be a 0.100 mol dm⁻³ solution of NH₄⁺ ions. Since there are two NH₄⁺ ions in each formula unit of (NH₄)₂CO₃·H₂O, the mass needed is stated in option **A** 4.56 g.

Question 11

Option **A** was a common incorrect choice. Option **A** cannot be correct since by definition a conjugate acid-base pair differs only by a single H⁺ ion. Option **C** is correct because if OH⁻(aq) is added it will react with H₃O⁺ ions. This will cause the equilibrium to move to the right.

Question 20

The most commonly chosen incorrect answer was option **B**. Candidates choosing this option did not determine two of the six possible isomers. The correct response is option **D**. The structures of these isomers are:

- pent-1-ene
- cis pent-2-ene
- trans pent-2-ene
- 2-methyl but-1-ene
- 2-methyl but-2-ene
- 3-methyl but-1-ene.

Question 29

Option **D** was a common incorrect choice. The empirical formulae of the products of acid hydrolysis of each of the options are:

- A** CH₂O and CH₃O
- B** CH₂O and CH₂O
- C** C₃H₆O₂ and C₃H₈O
- D** is not hydrolysed.

Therefore, option **B** is the compound that gives two products with the same empirical formula.

Question 32

The most commonly chosen incorrect answer was option **C**. Candidates were confident that statements 2 and 3 are correct, but were not as certain about statement 1. Statement 1 is true; there are three bonds between the two atoms so the ten valence electrons are arranged as :C≡O: and there are two lone pairs in one molecule.

Question 38

Option **A** was a common incorrect choice. Candidates were confident that statements 1 and 2 are correct, but were not as certain about statement 3. If bromoethane reacts with ethanolic KCN, the organic product is propanenitrile, not ethanenitrile, so statement 3 is incorrect.

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key messages

- A good and detailed knowledge of all areas of the syllabus and the ability to apply relevant knowledge to different situations are essential in order to perform well.

General comments

Excellent responses were seen in answers to all items on this paper. The best responses used specific and appropriate vocabulary within the correct context. Weaker responses used specific vocabulary in a less precise manner and produced ambiguous answers.

There were some question items which candidates found demanding, for example **Questions 1(b)(i), 4(b) and 4(e)(iv)**; even so, there were candidates able to apply their knowledge to these novel situations in an accurate and detailed manner. In these items, better performing candidates made use of the details provided in the question stem.

In general, candidates performed less well when attempting organic chemistry questions.

Comments on specific questions

Question 1

- (a) (i) The shape of a p orbital as two equal sized lobes was well known; many correct diagrams were seen. Weaker responses drew shapes that showed a circle in the centre of the two lobes. In the absence of an indicated label or axis it was not possible to ascertain if the circle represented the origin of an axis or a region of volume between the two lobes, where there was a chance of finding an electron. Occasionally, three p orbitals were shown rather than one.
- (ii) Detailed equations describing the first ionisation energy of silicon with appropriate symbols were seen. Some responses showed equations with no or incorrect state symbols or showed the process with the arrow representing a reaction in equilibrium. Confusion was seen in equations that produced negatively charged ions or added an electron to a silicon atom to form a positive ion.
- (iii) Relevant details that explained the general increase in ionisation energy across Period 3 were well known and some very thorough explanations were seen. Some answers were incomplete; often omitting any reference to shielding effect.
- (iv) Many answers showed correct interpretation of the graph, deduced that **A** was a Group 13 element and explained their reasoning clearly. Many responses that assigned **A** to the wrong group were able to provide answers that appreciated that the *significant increase in ionisation energy after the third electron was removed* was key to deducing to which group element **A** belonged.
- (b) (i) This calculation was demanding; many answers were seen that used all the information provided to calculate the relative abundance isotope silicon-30. Weaker responses produced a general equation to represent the relationship between relative atomic mass and the abundance of the three isotopes but struggled to use the relationship between the total abundance of silicon-29 and silicon-30. The weakest answers attempted to make this calculation with no reference to the relative atomic mass of silicon.

- (ii) The majority of candidates deduced that the structure and bonding of silicon nitride was *giant and covalent*. Excellent responses were seen that used all the information given to explain their reasoning; others lacked appropriate detail. A common misconception described the forces holding the giant structure together as strong intermolecular forces. The idea of the structure lacking mobile charge carriers when molten was often ignored.
- (c) (i) In many cases, the products of combustion of C_2H_5SH were deduced correctly. Occasionally, sulfur or hydrogen sulfide was described as a product. Some equations were not balanced or were incorrectly balanced.
- (ii) A description of the formation of acid rain as an environmental consequence for the release of sulfur dioxide into the atmosphere was well known, as was a description of the effect of acid rain on the environment. Some answers correctly described the process involved to make acid rain from sulfur dioxide emissions; this was not a requirement of the question.
- (d) (i) Good responses appreciated that there would be no change in the mixture at equilibrium and gave an appropriate explanation in terms of the number of moles of gaseous reactants and products in the equation. Some confusion was seen in answers relating the effect of increasing pressure on the rate of reaction.
- (ii) The idea that a higher temperature was required to increase the yield of this endothermic reaction was seen in many explanations. Inappropriate units, for example kJ/mol were seen and quite a few answers gave a value in degrees Celsius, even though the figure quoted in the question was in Kelvin. A small number of responses explained the use of an increase in temperature in terms of an increase in rate.

Question 2

- (a) The correct formula of aluminium oxide was often described; in some cases the formula of silicon(IV) oxide and/or phosphorus oxide was described incorrectly. The acid/base behaviour was less well known. Many answers described silicon(IV) oxide as amphoteric and responses that described sodium oxide as acidic and all the other oxides as basic were also seen.
- (b)(i) The majority of answers showed a good understanding of the term 'amphoteric'.
- (ii) Ionic equations representing the reaction between magnesium hydroxide and hydrochloric acid were rare. Many responses made no attempt to show the ionic equation but gave the full equation for the reaction. It was common to see the formula of magnesium chloride referred to as $MgCl$ rather than $MgCl_2$. Some answers attempted to show all the ions including the spectator ions.
- (iii) There were good answers, which gave detailed observed differences between the reactions of strontium and strontium hydroxide with water. Many answers did not include any observed difference or incorrectly stated that there would be effervescence when strontium hydroxide is added to water.
- (iv) The trend in solubility of Group 2 hydroxides was well known.

- (c) (i) Many responses used the ideal gas equation to find the amount of carbon dioxide. Of these, many converted the pressure, temperature and volume into the appropriate units and used the Data Booklet to find the gas constant.
- (ii) The majority of responses used the equation to appreciate the stoichiometry of the reaction between sodium peroxide and carbon dioxide. Correct calculations to find the mass of sodium peroxide using its formula mass and the answer produced in (c)(i) were common. Occasionally, the mass of carbon dioxide rather than sodium peroxide was calculated.
- (iii) Few answers showed correct 'dot-and cross' diagrams of the peroxide ion. Many responses showed the shared pair of electrons between the two oxygen species. Only a small number appreciated that there should be a total of 8 electrons on each oxygen ion to form the O_2^{2-} .

Question 3

- (a) (i) Relevant observations were described by many candidates. Some answers incorrectly described chlorine as a yellow gas rather than green or suggested that effervescence or a precipitate would be seen.
- (ii) Many correctly named the type of reaction of phosphorus pentachloride with water as hydrolysis. Hydration, neutralisation and redox were common incorrect answers.
- (iii) Good answers described the change in oxidation number of phosphorus and nitrogen and related these processes to oxidation and reduction. Many candidates appeared to have more difficulty deducing the oxidation numbers of nitrogen in the nitrogen containing species. The weakest responses described changes to the oxidation state of hydrogen and oxygen.
- (b) (i) The idea that a base is a proton donor was well known.
- (ii) Good three-dimensional representations of the ammonium ion and correct bond angle were seen. Weaker responses made no attempt to show the three-dimensional structure or produced confused diagrams. It was a relatively common mistake to see tetrahedral structures with two straight line bonds opposite each other, even though this suggests that the H–N–H is sitting in the same plane. Some answers suggested that the bond angle would be 107° rather than $109 - 109.5^\circ$.
- (iii) The majority appreciated that diammonium phosphate is used as a fertiliser.
- (c) (i) The reaction between phosphorus pentachloride and ethanol was not well known. The correct phosphorus containing product was rarely identified and it was common to see H_2O rather than HCl produced.
- (ii) Many candidates appreciated that a substitution reaction was involved when phosphorus pentachloride and ethanol react together to make ethanol.
- (iii) A small proportion of excellent descriptions explained why hydrogen iodide is not prepared using sulfuric acid. These answers identified sulfuric acid as a strong enough oxidising agent to oxidise hydrogen iodide to iodine. Some confused the iodine species involved during the reaction. The weakest responses discussed the thermal decomposition of hydrogen iodide.
- (iv) Many answers stated the correct trend in reactivity of the three halogenoalkanes. There were excellent responses, which explained this trend in terms of the increase in strength of the carbon–halogen bonds; there were a small number who quoted correct bond energies to support their answer. Weaker responses described 'decrease in bond strength down the group' but did not specify which bond they were referring to. Quite a few candidates stated that it was the hydrogen–halogen bond strength or difference in electronegativity of the halogens which was responsible for the difference in reactivity.

Question 4

- (a) There were some clear and accurate diagrams showing the mechanistic details for the reaction of **G** with hydroxide ions to make prenol. Many answers showed precise placing of the start and finish of a curly arrow to show the movement of an electron pair, either from a bond or a lone pair of electrons, to the new bond that is made. Some did not appreciate that the hydroxide ion is the nucleophile responsible for this reaction and attempted to show a mechanism involving Na–OH.
- (b) (i) In order to deduce the correct structure, candidates had to work out the three different isomers that could be made when prenol reacts with steam and then use the information that '**J** did not react with 2,4-DNPH' to deduce the structure of **J**. This was a demanding question, but correct structures of **J** were described by some. However, straight-chain molecules with two alcohol groups were common, even though the structure of prenol was given as a branched structure.
- (ii) Some candidates used all the information given to show a correct structure. Many answers showed a product with carbonyl groups or carboxylic acid groups, which suggested that some candidates were attempting to identify the compound made after oxidation with potassium dichromate(VI).
- (iii) In order to answer this question, details given in the stem of the question needed to be used; this included the idea that **K** and **L** are a pair of isomers formed when prenol reacts with steam. They both react with potassium dichromate to form the same compound, **M**. Although there were some answers that identified optical isomerism, many incorrect descriptions of geometric isomerism, chain isomerism and structural isomerism were seen.
- (iv) Writing balanced equations that represent the oxidising agent of the reaction as [O] proved difficult for many. Although some correct equations were seen, it was common for hydrogen gas rather than water to be described as a product and equations were rarely balanced.
- (c) (i) A description of the bromine water turning from brown to colourless to confirm the presence of the alkene group was common. A small number of answers described the addition of potassium manganate(VII), which would not be appropriate as it would also react with the primary alcohol group in a sample of prenol.
- (ii) Many answers described the correct repeat unit of poly(prenol). Where mistakes were seen, they often involved transcription errors or produced structures that showed a string of repeat units joined together with no identification of the repeat unit involved.
- (d) (i) Some candidates correctly named **N**; many others incorrectly identified the position of the methyl group and/or alcohol group and referred to it as 2-methylbutan-4-ol.
- (ii) Identification of nickel as a heterogenous catalyst was seen in many answers. There was confusion in some cases where words with 'hetero' were used but which had a totally different meaning, for example 'heterolytic' and 'heterozygous'.
- (iii) A significant number of answers showed correct skeletal structures of the ester made when isoprenol reacts with ethanol and sulfuric acid. Weaker responses had difficulty describing the ester link or showed an incorrect carbon backbone.
- The majority of answers identified a commercial use for **Q** as a perfume or solvent.
- (e) (i) Some candidates appreciated that the progress of the reaction could be followed by looking at the change in absorption within the range $1500\text{--}1680\text{ cm}^{-1}$, which corresponds to the disappearance of C=C. Weaker answers suggested that the absorbance which corresponded to the C–H bond could be monitored, even though C–H bonds are present in the reactant and the product.
- (ii) Identification of potassium cyanide or sodium cyanide to convert the chloroalkane into its corresponding nitrile was seen. Some responses incorrectly identified the reagents required to convert a carbonyl compound to a hydroxy-nitrile instead.
- (iii) Identification of the type of reaction involved in the conversion of a nitrile to its corresponding carboxylic acid was well known. The most detailed answers described it as acid hydrolysis but the majority referred to the reaction as hydrolysis.

- (iv) This was a demanding question. A small number of detailed explanations related the low yield to the unstable primary carbocation made during this reaction. Many answers were seen that discussed rate of reaction, activation energy and bond strength to the low yield but did not attempt to explain that another product could be formed from an intermediate with a greater positive inductive effect.

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Paper 9701/33
Advanced Practical Skills 1

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. 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.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method and the presentation of results. The calculation caused problems for some, as parts of the information given in the question were disregarded by candidates.

- (a) The results in this part tended to be centre-dependent. The common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place and not providing a concordant last titre.
- (b) The majority of candidates determined the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm³.
- (c) (i) Candidates are instructed to show appropriate significant figures in final answers to all parts and they were reminded of this in (i); any answer that was not to three or four significant figures was not credited.

- (ii) Many candidates calculated the moles of NaOH correctly. Some candidates omitted dividing by the relative formula mass or dividing by 1000.
- (iii) Nearly all candidates gave the correct equation; many gave incorrect state symbols. The common errors were NaCl(s), contrary to what they would have observed in the titration, and H₂O(aq). Almost all candidates realised that the number of moles of HCl would be the same as the moles of NaOH.
- (iv) The calculation of the concentration of HCl in **FA 2** proved to be the most challenging part of the question for many. Several approaches were seen; it was important that the steps employed to calculate this concentration are logical and clearly displayed on the candidate's script. Many candidates only multiplied their answer in (iii) by 100, which was incorrect.

Question 2

Many candidates gained good results in both of their experiments. The responses in the rest of the question varied considerably. A wide spread of marks was seen in the analysis, conclusions and improvements sections.

- (a) The majority of candidates recorded their results in a clear, logical manner. The most common error was to record thermometer readings either to an integer value or to .00 °C. A large majority of candidates reported an increase in temperature. The ΔT values varied considerably from centre to centre with some being as low as 5.0 °C and others as high as 45.0 °C. This highlights the importance of including supervisor with the return of candidate scripts.
- (b) The responses to this section appeared to be largely centre-dependent, with many obtaining full marks but others gaining none or one.
 - (i) This part was answered correctly by most candidates with almost all knowing the equation to find the heat energy produced. The most common error was to use the mass of MgO instead of the volume of solution, thus ignoring the information given regarding 4.2 J being required to change the temperature of 1.0 cm³ by 1.0 °C.
 - (ii) This was also answered correctly by a large majority of candidates. Some candidates, incorrectly, used 24 as the relative atomic mass, A_r , of Mg instead of 24.3, as given in the Periodic Table on the question paper.
 - (iii) Most candidates used their answers to (i) and (ii) correctly. Some incorrectly gave a positive sign for an exothermic reaction, gave an answer to five or more significant figures, or did not divide by 1000 to convert J into kJ.
- (c) Better performing candidates answered this section successfully; many others did not attempt it. Of those who did, most were able to calculate the moles of HCl used in (a) but did not apply the stoichiometry of the equation so could not access the mark.
- (d)
 - (i) Most candidates performed well with very few using a mass of MgCO₃ outside the range specified. There was greater agreement between centres for the value of ΔT in this part than in (a).
 - (ii) Most candidates reported fizzing or effervescence; far fewer commented on the vigour of the reaction and even fewer the colour of the solution formed. The question asked for observations so more than one observation was expected.
 - (iii) There were many correct answers here. Those using the mass of MgO in (b)(i) tended to use the mass of MgCO₃ in the heat energy change. A few used the number of moles of MgO from (b)(ii) instead of calculating and using the moles of MgCO₃.
- (e) Many candidates sketched a Hess' diagram to help them with the calculation. Some were less successful as they had arrows going the wrong way; a common error was to subtract (b)(iii) from (d)(iii). Some candidates ignored their own results and used the default values; this was allowed in all cases. As reversing the equation would show a thermal decomposition reaction it was expected that candidates would recognise that MgO(s) + CO₂(g) → MgCO₃(s) would be exothermic.

- (f) Credit was rarely awarded as most answers involved changes to the apparatus, despite the wording of the question. Of those gaining credit, the majority suggested increasing the mass of **FA 4** and/or **FA 5**; only a small minority suggested collecting results for plotting a cooling curve.
- (g) It was rare to award both marks and some candidates scored zero. Many candidates correctly identified a single reading error for the balance; far fewer doubled this for calculating the maximum percentage error in the mass of MgO calculated in (a).

Question 3

This proved to be difficult for many though some high marks were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It was noticeable that few supervisors provided observations in (a), (b)(i) and (b)(ii), which made it difficult to ascertain whether unexpected observations were due to poor technique or to contamination of the chemical supplied.

- (a) Most candidates recorded effervescence; far fewer went on to test the gas. Many assumed the gas was CO_2 from a carbonate and claimed it formed a white precipitate with limewater. Of those correctly identifying H_2 as popping with a lighted splint, only a small number went on to suggest that **FA 6** was a metal.
- (b)(i) Few candidates supplied enough correct observations to gain more than one mark. Most candidates noted the melting of **FA 7** but rarely reported that the liquid turned yellow. Some candidates noted effervescence on further heating; far fewer tested the gas with a glowing splint. Many used incorrect terminology for the change observed on cooling; the use of the term 'precipitate' was inappropriate. Only a few candidates included the colour of the solid formed.
- (ii) Responses to this part varied considerably and it was rare to award full credit. It was insufficient in test 1 to write 'colourless solution' when adding acidified aqueous potassium manganate(VII) to **FA 9** as this did not indicate the change in colour of the reagent. Some candidates lost credit in test 2 by adding an acid to the precipitate formed with **FA 9**, even though the initial instructions stated that no additional tests should be carried out. Many candidates reported effervescence on adding aluminium foil in test 3 and correctly identified NH_3 produced with **FA 8**. However, red litmus paper was also reported as turning blue with **FA 9**, which suggested poor technique. Very few candidates tested for H_2 .
- (iii) Correct names or formulae were often given. Some candidates did not attempt this part or suggestion ions such as Cl^- even though no test for halides had been carried out.
- (iv) There were few correct answers given, with many candidates appearing to have a poor understanding of ionic equations. Of those giving a correct equation, many omitted state symbols or gave incorrect ones; $\text{BaSO}_4(\text{aq})/\text{BaSO}_3(\text{aq})$ was a common error. A number of 'insoluble' compounds of sodium were suggested.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

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Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

The standard of experimental skills varied considerably and was generally centre-dependent. Most candidates were able to gain credit in **(a)** and **(b)**. Credit for the rest of the analysis and conclusion sections was only awarded by those able to explain how their knowledge of rates of reaction applies to the questions set.

- (a)** Most candidates gained credit for presentation of results. The errors seen included use of the word 'weight' instead of 'mass' and omission of units or quoting incorrect units. The unit of volume used in 9701 chemistry is always based on the SI unit of m^3 , i.e. cm^3 or dm^3 . Hence, m^3 is not appropriate even though some manufacturers use this. The accuracy marks tended to be centre-dependent and indicated that some candidates were much more familiar with this type of experiment than others. In a few centres, the candidates' volumes of gas collected varied by over 100 cm^3 , while others reported volumes all within a realistic range of each other and of the supervisor.

- (b)(i)(ii)** Most candidates calculated the number of moles of oxygen collected in 4 minutes. Some candidates omitted the division by 1000 to convert their answer from cm^3 to dm^3 . The stoichiometry of the equation was ignored by the majority of candidates. However, many gained credit by dividing their number of moles by 0.03 dm^3 , the volume of **FB 1** used. Some candidates inappropriately gave their answer to one, five or five or more significant figures in either **(i)** or **(ii)**.
- (c)** A number of candidates incorrectly agreed with the 'candidate' even though their experimental results contradicted the statement. Many candidates failed to explain that the decrease in rate was caused by a decrease in frequency of collision owing to decreased concentration.
- (d)** The most common correct response was that there would be no change in the final volume of gas collected as MnO_2 was a catalyst. However, many responses were vague; for example, 'faster reaction' needed clarification. The response of 'no effect' needed clarifying with 'on final volume' as the question asked about results obtained.

Question 2

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method, the presentation of results and the calculation using the titration data. However, many candidates had difficulties with the sections dealing with errors.

- (a)** The results in this part tended to be centre-dependent. Common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place and not providing a concordant last titre.
- (b)** The majority of candidates determined the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3 .
- (c) (i)** Most candidates calculated the moles of potassium manganate(VII) correctly.
- (ii)** Most candidates calculated the moles of hydrogen peroxide correctly.
- (iii)** Most candidates calculated the concentration of hydrogen peroxide correctly; others dropped a trailing zero. An answer to two significant figures did not reflect the precision given for the concentration of the oxidising agent nor that of the apparatus used; three or four significant figures should have been shown.
- (d)** Candidates struggled to adequately answer this question. Candidates should be given the opportunity to discuss errors and improvements when carrying out practical exercises in class. The most frequently seen credit-worthy error and improvement involved the loss of gas and the use of a divided flask or similar. (An example of a discussion point for teachers and learners could be the reason that using a thistle funnel to add the hydrogen peroxide is unsuitable.) Some candidates suggested using a burette instead of a measuring cylinder without specifying which one it was replacing. Answers based on human error, use of an assistant or camera are never credited.
- (e)** A minority of candidates correctly stated the acid was in excess, so the volume added need not be accurate. Many candidates agreed with the 'student' and gave examples of error for each of a pipette and a measuring cylinder. Others, incorrectly, stated that a pipette could not measure 20 cm^3 , these candidates were not aware of the range of pipette volumes available or graduated pipettes. A minority of candidates suggested that it would be dangerous to pipette the acid by mouth, these candidates did not appear to be aware of pipette fillers. These are examples of where class discussion would be beneficial.

- (f) (i) The calculation was carried out correctly by a small majority of candidates. Every combination of the figures was seen; the most common errors were to divide by the actual rather than the theoretical concentration or to divide by the mean of the two values.
- (ii) Only a minority of candidates were aware of the slow decomposition of hydrogen peroxide at room temperature.

Question 3

This proved to be difficult for many candidates, although some good responses were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It was noticeable that few Supervisors provided observations in (a)(i), which made it difficult to ascertain whether unexpected observations were due to poor technique or to contamination of the chemical supplied.

- (a) (i) It was insufficient in test 1 to write 'colourless solution' when adding acidified aqueous potassium manganate(VII) to **FB 7**, as this did not indicate the change in colour of the reagent. Use of the Qualitative Analysis Notes would have been of assistance to some in test 2, as the effect of adding excess NaOH(aq) to the precipitate with **FB 6** was often omitted. It was apparent from the bubbling reported that many candidates boiled the alkaline mixtures rather than just warming sufficiently for any ammonium ion present to react. Many candidates gave false positives for ammonia gas in this test. Many candidates noted the red-brown precipitate in the final part of test 3 with **FB 7**; fewer noted effervescence with H₂O₂(aq) or that the precipitate was insoluble in excess NaOH(aq). The words 'in excess' were essential as, by definition, precipitates are insoluble so 'red-brown precipitate insoluble' is insufficient. Test 4 produced many correct observations but some candidates added an acid to the precipitates formed with Ba²⁺(aq), thus disregarding the initial instruction that 'no additional tests should be attempted'. There was a mixed response to test 5. 'Ammonia produced', is a conclusion and not an observation so could not be credited. While some candidates noted effervescence in both the tests using NaOH(aq) and Al foil, others only commented on the change of colour of red litmus paper. Candidates should be aware that hydrogen gas is formed in this test and so be prepared to prove its presence. Few candidates reported a pop with a lighted splint with **FB 7** and many incorrectly reported the red litmus turning blue. Unless there was some indication that a gas was being tested, then the red to blue with **FB 8** could not be credited.

(ii)–(v)

The most common error in this section was to omit a reason for the choice of ion. The relevant reagents should also have been mentioned. Some candidates confused cations and anions.

Most candidates recognised the cation Fe²⁺ in (ii) and knew the two possible anions, SO₃²⁻ and SO₄²⁻, in (iii). Most were able to name a cation in (iv) that could not be present, but many did not specify that this was shown by the negative result when tested with NaOH(aq). It was essential for candidates to indicate that the ammonia was formed on adding Al foil as well as NaOH(aq) to the NO₃⁻ in (v).

- (b) This part was poorly answered by many; nevertheless, some candidates gained full credit. Some candidates were able to draw an appropriate table and include at least one test. Few candidates suggested suitable named reagents and the conditions needed for an esterification test. Most of those who stated propan-1-ol suggested using acidified potassium manganate(VII) or acidified potassium dichromate(VI), although the colour changes for the latter were not always correct. The most popular test for gaining a positive result with ethanoic acid was the addition of a named carbonate and noting effervescence or testing the gas with limewater. There were many incorrect reagents suggested such as Na, PCl₅ and SOCl₂; these would have reacted with both organic compounds. Other reagents suggested were only suitable for identifying the presence of an aldehyde or a CH₃CH(OH)–/CH₃CO– group.

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<p>Paper 9701/42 A Level Structured Questions</p>

Key messages

- Better performing candidates wrote legibly and paid particular attention to the clarity of their writing in the formulae of compounds or the charges on ions.
- Crossing out and overwriting so that, for example, a 2 and a 3 in a formula are both still visible and legible, is ambiguous and credit cannot be awarded. If a candidate wishes to change an answer, this should be crossed out thoroughly and then rewritten afterwards in another space. Blank space on the question paper or a continuation sheet can be used to rewrite an answer. Candidates must clearly identify the question number of this is necessary.
- Where a question asks for a comparison of the properties of two substances or ions, candidates should always make it very clear which of the two they are describing in each part of their answer. The use of the word 'it' should be strongly discouraged in such answers.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.

General comments

Many very good responses and a significant number of excellent ones were seen. Many candidates were able to work through to the end of the paper, with very few blank responses seen.

Comments on specific questions

Question 1

- (a) This was answered correctly by the majority of candidates.
- (b) (i) Candidates found this a very challenging question, both in chemical and mathematical level of demand.
- (ii) Many candidates did not realise that they had to use +1.07 V and their answer to (i) in order to answer this question.
- (iii) Most candidates were able to deduce the identities of the oxidising agent and of the reducing agent and were able to balance the equation.
- (c) Many excellent answers to this calculation were seen, including many different approaches. The methods of better performing candidates were clearly explained. The commonest sources of errors were included:
- calculations that stopped after reaching 16 200 C and 0.0802 mol Cu
 - use of the value 96 500 C from the Data Booklet and therefore calculating 6.03×10^{23}
 - use of the value 6.03×10^{23} from the Data Booklet.
- (d) Some excellent answers were seen which explained, using E^\ominus values, why hydrogen is given off at the cathode. Many answers focused on the presence of the sulfate ion, but as this ion is negatively charged it will not be involved in the formation (or otherwise) of magnesium.

Question 2

- (a) This was answered well. Some candidates did not specify what is being halved when explaining the half-life of a reaction. Better responses included the phrase 'the amount of reactant' in their responses; other candidates omitted the expression 'time taken'. Explanations of the rate-determining step were usually correct.
- (b) Many candidates found this very difficult; although some excellent scripts were seen. The importance of temperature control, and the use of a large excess of the other reactant, were very rarely referred to.
- (c) This was answered well.

Question 3

- (a) (i) Most candidates could calculate the correct concentration.
- (ii) This was usually done well. A significant number of candidates calculated K_a but did not go on to calculate pK_a .
- (b) (i)(ii) Ionic equations were used to answer the questions most successfully, but molecular equations were also acceptable. Some equations were not balanced for charge, or for substances, or for both.
- (c) (i) Most candidates could do this successfully; others did not show their working, which was a requirement of the question.
- (ii) Some calculations included rounding errors. Some candidates did not realise that $(H^+) = (OH^-)$.

Question 4

- (a) The correct answer was seen on most scripts. The small number of errors were mostly stoichiometry; a very small number of algebraic errors were also seen.
- (b) Candidates are strongly advised to use the Gibbs equation to answer a question such as this. Candidates who used $\Delta S_{total} = \Delta S_{surroundings} + \Delta S_{system}$ almost without exception became confused and performed poorly.
- (c) The key factor in the explanation was the decrease in the number of moles of gas present.

Question 5

- (a) The flame colours were not well known. The flame colour of strontium was sometimes confused with the flame colour of calcium. Not all candidates mentioned the formation of a white solid product in each case.
- (b) (i) Full credit was often awarded here. A number of equations for the decomposition of $CaCO_3$ incorrectly included O_2 in either the reactants or the products.
- (ii) A precise statement, such as 'to raise pH' or 'to neutralise acidic soil' was often seen. No credit could be awarded for a vague statement such as 'to control pH'.
- (iii) This explanation was well known and clearly described by many candidates.
- (c) Commonly seen incorrect statements included:
- $NaOH(aq)$ and $BaCl_2(aq)$ produce a white precipitate
 - steamy fumes of HCl are seen when $H_2SO_4(aq)$ and $BaCl_2(aq)$ are mixed.
- (d) This explanation was well known and clearly described by many candidates.

Question 6

- (a) This definition was well known.
- (b) Some candidates were able to describe the observations; fewer gave correct formulae. It was common to see an incorrect formula such as $(\text{Cu}(\text{NH}_3)_2(\text{H}_2\text{O})_4)^{2+}$ after a few drops of dilute ammonia and an incorrect formula such as $(\text{Cu}(\text{NH}_3)_6)^{2+}$ after an excess of dilute ammonia.
- (c) This proved to be one of the most difficult questions on the paper to many candidates. A large number of answers explained the origin of colour in a solution of $\text{Cu}^{2+}(\text{aq})$. These answers did not answer the question, which was about the *change* in colour during the process described. However, some excellent answers were seen in which ligand exchange, the consequent change in ΔE value and the consequent change in the frequency or wavelength of light absorbed were all clearly described.
- (d) Many candidates incorrectly focused on the presence of sulfate ions. Candidates who realised that this is a redox reaction often quoted the necessary data and were able to write a balanced equation.
- (e) (i) Some responses included ionic charges are written outside the final set of square brackets.
(ii) The majority of candidates were able to calculate the correct answer here.

Question 7

- (a) (i) This was answered well. Some incorrect linkages and ring orientations were seen and some candidates ignored the instruction to 'include two repeat units'.
(ii) Many candidates placed more than one tick in the table and so credit could not be awarded.
(iii) Many candidates knew that a polyamide is biodegradable; a smaller number knew that this is due to hydrolysis.
(iv) This was answered well.
(v) This was answered well. Some responses did not state that the acids used in step 1 must be concentrated.
- (b) (i) Some candidates were able to describe each of three terms; others need more practice recalling these standard definitions.
(ii) Most candidates correctly stated amide or peptide bonds.
(iii) Many candidates knew the answer was hydrogen bonding; a smaller number described clearly the groups of atoms involved. Better performing candidates stated, 'from the H on N-H to the O of C=O'. A significant number of candidates wrote 'from COOH to NH₂' and did not gain credit.

Question 8

- (a) This was answered well by many; others, incorrectly, said that the bromine should be aqueous..
- (b) Many candidates knew which compound was being described and could use the correct conventions to name it. Some candidates did not read the question and answered 'HBr'.
- (c) The importance of adding nitrile groups to extend the carbon chain was only appreciated by a minority of candidates.
- (d) The reagents and conditions were correctly stated by some candidates.
- (e) (i) This was well known.
(ii) This was not well known. A number of answers incorrectly suggested compounds that could only be obtained by reduction of ethanedioic acid.

- (f) Many candidates found it difficult to gain credit here. Those who did well usually focused on either the strength of the O-H bond, or the stability of the anion formed.
- (g) (i) It was common for the peak at δ 12.7 to be identified. Some candidates were not sufficiently specific; stating 'alkane' does not distinguish between the CH proton and the CH₃ protons.
- (ii) Most candidates' answers included 'quartet' or 'quadruplet'. Credit was not awarded for 'three neighbouring hydrogen atoms'; 'three hydrogen atoms on the neighbouring carbon atom' was acceptable.
- (iii) This was often answered well.

Question 9

- (a) (i) This was found to be difficult.
- (ii) This was found to be very difficult. The question states that 'the two electrons in the lone pair on the nitrogen atom of the amide group' become part of the single delocalised system. Better performing candidates deduced that the NH₂ group must be planar with a bond angle close to 120°.
- (b) (i) Some candidates could correctly draw the structural formula of E.
- (ii) If candidates stated 'aqueous ammonia' or 'ethanolic ammonia' is used, the solution should have been described as concentrated. This would minimise the formation of other products.
- (c) This was found to be difficult. The two compounds were the products of acidic and alkaline hydrolysis of the amide.
- (d) (i) This was usually answered well.
- (ii) Many candidates found it difficult to gain full credit. Better performing candidates focused on the lone pairs on the nitrogen atoms and whether neighbouring groups would donate or remove electron density from those lone pairs. Some candidates believed phenylamine and C₆H₅NH₂ to be two separate compounds.
- (e) This question asked for the peak height to be calculated from the number of carbon atoms rather than the other way round; many candidates answered it well. Some candidates wrongly deduced that there are either five or seven carbon atoms in a nicotinamide molecule.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

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 even if unusual chemicals, such as in **Question 1**, are used. It was apparent that many candidates could not provide suitable details of condensers in **Question 1(a)(i)**; knowledge about the key points of reflux was weak in **Question 1(a)(ii)-(iv)**; the required apparatus for distillation in **Question 1(b)(i)** was frequently unworkable.
- 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 1(d)** required two reasons why CH_3I was the preferred halogenoalkane and correct answers were often contradicted by inclusion of a third, and sometimes fourth, incorrect reason.
- 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.
- If a candidate considers a point on a graph to be anomalous then it should be circled, whether this is required or not. This would help Examiners appreciate why points may have been ignored when drawing a line of best fit.

General comments

Question 2 had multi-step calculations. It is important that candidates do not round in early steps of a calculation. Rounding should be done 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, \odot , 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) Many candidates were not aware that cooling water always enters a condenser via the lower inlet, whether this is for a reflux set-up or for distillation. The reason for having cooling water enter the lower inlet is to ensure the central tube is always surrounded by cold water.

Many candidates seemed unaware of this basic A level apparatus set-up, which might suggest that these candidates had not seen an experiment involving a reflux set-up.

- (ii) Many candidates correctly suggested either drop-by-drop addition of the solution or using an external cooling bath as a measure of controlling a very exothermic reaction. A common misconception was to use anti-bump granules to reduce temperature rise.

- (iii) Most candidates were not familiar with the idea of why a reflux apparatus set-up is used. It is used to prevent volatile vapours escaping from the reaction mixture. This is done by condensing the volatile vapours and allowing them to run back into the flask. The question asked candidates to consider responses which did not relate to increasing the rate of reaction; a point many candidates overlooked.
- (iv) The fact that most candidates thought that placing a bung in the top of the condenser was an improvement, reinforced the idea that candidates were unfamiliar with a reflux set-up. A relative few realised that pressure would build up, causing the apparatus to 'pop apart' or 'explode'.

Some candidates thought using a bung deliberately to increase the pressure would beneficially either increase the rate of reaction or favour the equilibrium yield.

- (b)(i) It was expected that candidates would draw a condenser in the diagonal 'distillation' position and draw the system sealed, except for the delivery end of the condenser.

Many drew a condenser attached to the flask neck which originally held the tap funnel or drew condensers receiving vapours at a lower point than they would leave. Thus, any vapours going into such a condenser would simply condense and run back into the mixture rather than distilling over.

- (ii) This data-based question was correctly answered by most candidates. The key point was that ethanol had a lower boiling point than the other two substances (or the lowest), rather than just a low boiling point.
- (iii) Many candidates misunderstood this relatively simple question. Candidates were told 4-aminobenzaldehyde is soluble in hot water, but not in cold water. From previous parts, they would have been aware that the solution also contained aqueous inorganic substances.

It was expected that candidates would cool the solution, then filter the cold solution, making sure the residue was rinsed with (cold) water to remove any inorganic impurities.

Many misinterpreted the question and treated it as a purification by recrystallisation process. Many others simply crystallised by heating to dryness; others suggested evaporating the product or heating to constant mass.

- (c) Very few candidates realised that under acidic conditions 4-aminobenzaldehyde forms a dimer type product in a condensation reaction and that the loss of water meant the mass of the dimer molecule would be less than the two molecules of 4-aminobenzaldehyde due to the loss of water.

Most struggled to give plausible responses.

- (d) This simple data handling question was poorly addressed. Very few candidates realised that the **lowest** carbon-halogen bond energy of CH_3I would mean a quicker rate of reaction, in comparison to the other two halogenoalkanes. Even fewer realised that a boiling point of 43°C meant that CH_3I would be a **liquid** at room temp whereas the other two boiling points (4°C and -97°C) meant the other two compounds would be gaseous.

Question 2

- (a)(i) The majority of candidates answered this calculation correctly.
- (ii) Most candidates could do the calculations; a lack of correct rounding and incorrect use of significant figures caused some to unnecessarily lose marks.
- (b) Most plotting was quite good, as were the straight lines of best fit. Some candidates relied on drawing a line of best fit by connecting first to last points; this method often results in credit being lost, unless the line gives equal numbers of points on each side of the line.

- (c) (i)** Most candidates could read the coordinates correctly; some were troubled by the difficult x -axis scale. A few did not know the (x, y) convention and others did not allow a sufficient range of values.
- Most candidates did not realise that the x -axis had a scale involving 10^{-3} and omitted this from their calculations of the gradient.
- (ii)** This was a challenging calculation, which involved deducing an answer based upon the response given in **(c)(i)**. The most common error was to calculate an answer in J rather than converting the value to kJ.
- (d) (i)** This question was designed to find out if candidates could use their graph to determine the reliability of the experiment. Candidates who performed less well suggested generic answers, such as a lack of repeat experiments. Better performing candidates based their responses on the relationship of plotted points to the line of best fit; some said that their points were all near their line of best fit when they clearly were not.
- (ii)** Many candidates did not understand that they had to calculate two values to provide a range for the enthalpy change for fusion from the literature values. Many who attempted these calculations often went wrong.
- Relatively few interpreted the question fully and often did not provide the essential comment about the accuracy of the value determined from the experimental procedure compared to the calculated range.
- (e)** Many did not appreciate that the use of the Hess cycle given in the question was the route to the answer. Where candidates did use the Hess cycle to determine answers, they did not address possible changes in an enthalpy value in expected terms such as 'more positive' or 'less negative'. 'Bigger' or 'higher' or 'lower' or 'less' do not convey the direction of an enthalpy change.
- (f) (i)** Most candidates secured the mark; some erroneously suggested the number of moles of naphthalene was changing.
- (ii)** The relationship, involving logs, negatives and division, proved too difficult for most candidates.