# CHEMISTRY

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Paper 9701/11
Multiple Choice

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

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## General comments

There were many very strong performances on this question paper and some outstanding ones. There was no evidence that candidates did not have sufficient time to answer all questions.

Candidates found **Questions 2**, **4**, **7**, **8**, **10**, **12**, **13**, **15**, **30**, **35** and **37** the most accessible and **Questions 9**, **20**, **28**, **32**, **33** and **38** more challenging.

## Comments on specific questions

### Question 9

The most commonly chosen incorrect answer was **A**. This suggests that some candidates assumed that two $MnO_4^{2-}$ ions give one $MnO_4^-$ ion and one $MnO_2$ formula unit. However this is a redox reaction. $MnO_4^{2-}$ to $MnO_4^-$ involves the loss of one electron while $MnO_4^{2-}$ to $MnO_2$ effectively involves the gain of two electrons

as the oxidation number of Mn decreases from 6 to 4. In order to balance the electrons involved, three $MnO_4^{2-}$ ions give two $MnO_4^-$ ions and one $MnO_2$ formula unit.

**Question 20**

The most commonly chosen incorrect answer was **C**. **C**, pentan-3-one, would be reduced to pentan-3-ol. This will dehydrate to give cis and trans pent-2-ene; two isomers. **B**, butanone, would be reduced to butan-2-ol. This will dehydrate to give cis and trans but-2-ene and but-1-ene, three isomers.

**Question 28**

Many candidates incorrectly gave **B** as their answer. The answer **B** is obtained by 2.3×0.6=1.38. This does not take into account the different $M_r$ values of the reactant and the product.
Using an excess of oxidising agent and boiling under reflux for one hour would only be done if the carboxylic acid is the required product. 2.3 g is 0.05 moles of ethanol. The answer is **C** as the required product is ethanoic acid, since 0.05×60×0.6=1.8.

**Question 32**

The most commonly chosen incorrect answer was **A**. The choice of **A** requires statement **3** to be true, and $C_{60}$ cannot be described as 'giant molecular'. Since $C_{60}$ has pentagons of carbon atoms in its structure statement **2** is also untrue. Only statement **1** is true, every carbon atom in graphene, graphite and $C_{60}$ has an electron in a p-orbital giving rise to delocalised electrons.

**Question 33**

The most commonly chosen incorrect answer was **B**. For the majority of candidates statement **2** was the key to this question. An enthalpy change of combustion is defined as the energy change when complete combustion takes place and the equation in the question involves incomplete combustion, so statement **2** is false.

**Question 38**

The three incorrect choices each attracted approximately equal numbers of candidates, suggesting many candidates may have guessed. Statement **1** is true because a primary halogenoalkane reacts mainly by an $S_N2$ mechanism. Statement **2** is false. The carbon atom in $(CH_3)_3CCl$ will be less positive, not more positive, due to the inductive effect of three alkyl groups. Statement **3** is false, as it is a carbon atom not the chlorine atom that is attacked.

# CHEMISTRY

**Paper 9701/12**
**Multiple Choice**

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

## General comments

There were many very strong performances on this question paper and some outstanding ones. There was no evidence to suggest that candidates did not have sufficient time to complete the questions.

Candidates found **Questions 1**, **3**, **5**, **7**, **8**, **11**, **12**, **15**, **21**, **22**, **30** and **33** the most accessible and **Questions 2**, **10**, **24**, **28**, **31** and **38** more challenging.

## Comments on specific questions

### Question 2

The most commonly chosen incorrect answer was **C**. **C** was perhaps attractive because $9.03\times10^{23}$ is 1.5 times Avogadro's number, but because the named substance is sulfur trioxide this will contain 4.5 moles of oxygen atoms.

**Question 10**

Almost half the candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**. As the temperatures are the same $K_p$ doesn't change, so the answer is **A**.

**Question 24**

The most commonly chosen incorrect answer was **C**. The answer **C** comes about if 75% of 2.76 g is calculated but this does not take into account the different $M_r$ values of ethanol and ethanoic acid. The mass given, 2.76 g, is 0.06 moles of ethanol and under the conditions given the required product will be ethanoic acid, so 100% yield = 0.06×60 = 3.6 g. 75% yield is therefore 3.6×0.75 = 2.7 g, giving the answer **D**.

**Question 28**

The most commonly chosen incorrect answer was **B**. The answer is **A** because butan-1-ol has only one positional isomer, butan-2-ol, and propanoic acid has no possible chain isomers. **B** is not possible because ethanol has no positional isomers and butanoic acid has chain isomers. **C** is not possible because pentan-1-ol has two positional isomers. **D** is not possible because pentanoic acid has chain isomers.

**Question 31**

The most commonly chosen incorrect answer was **A**. The question therefore depended, for many candidates, on the electronic structure of a copper atom. Since copper is $4s^1 3d^{10}$ it does not have a filled 4s subshell.

**Question 38**

The most commonly chosen incorrect answer was **D**. Since each of the carbon atoms bonded to a chlorine atom will be chiral, if there are n monomer residues then the number of chiral carbon atoms is also n. There are, therefore, n chiral carbon atoms in each molecule. Statement **2** is therefore correct and the answer is **B**.

# CHEMISTRY

| Paper 9701/13 |
| Multiple Choice |

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

## General comments

There were many very strong performances on this question paper and some outstanding ones. Generally there was no evidence that candidates did not have sufficient time to complete the questions.

Candidates found **Questions 1**, **3**, **7**, **8**, **10**, **11**, **14**, **15**, **19**, **22** and **32** the most accessible and **Questions 21**, **23**, **24**, **30**, **34**, **38** and **39** more challenging.

## Comments on specific questions

### Question 21

The most commonly chosen incorrect answers were **A** and **B**. The structure should start with a cyclopentyl ring with an OH group and a methyl group on carbon atom 1. There is one carbon atom left to add.

- If this carbon atom goes on carbon atom 2 of the ring as a methyl group we have a molecule with two chiral centres and therefore four isomers.
- If this carbon atom goes on carbon atom 3 of the ring as a methyl group we have a molecule with two chiral centres and therefore four more isomers, making eight so far.
- If this carbon atom goes on the methyl group already attached to carbon atom 1 this becomes an ethyl group. This molecule is not chiral, giving one more isomer, making nine.

**Question 23**

The most commonly chosen incorrect answer was **B**. **B** will give a salt, not the acid, when hydrolysed by NaOH (aq). **A** involves a salt of propanoic acid which will give propanoic acid when $H_2SO_4$ is added.

**Question 24**

The most commonly chosen incorrect answer was **B**. **B** will give poly(ethene) which will not be oxidised by cold, acidified $KMnO_4$.**C** will give a polymer with one chlorine atom on every carbon atom. This will be hydrolysed to the structure given.

**Question 30**

The most commonly chosen incorrect answer was **A**. The six combinations are:
- butanoic acid and methanol
- methylpropanoic acid and methanol
- propanoic acid and ethanol
- ethanoic acid and propan-1-ol
- methanoic acid and butan-1-ol
- methanoic acid and methylpropan-1-ol

**Question 34**

The most commonly chosen incorrect answer was **D**. Since both reactions were the same and had the same catalyst, statement **1** is true. A calculation shows that statement **2** is true (0.04 moles of $H_2O_2$ give 0.02 moles of $O_2$ which has the volume stated.) Statement **3** is wrong as larger pieces of catalyst would give a greater time not a smaller time.

**Question 38**

The most commonly chosen incorrect answers were **B** and **C**.
- Statement **1** is correct – 2-bromobutane gives but-1-ene and but-2-ene.
- Statement **2** is not correct – 2-bromo-2-methylpropane gives methylpropene only.
- Statement **3** is not correct – 1-bromo-2-methylpropane gives methylpropene only.

**Question 39**

The most commonly chosen incorrect answer was **B**. Statement **2** gives ethanol. Statement **3** gives propan-1-ol. These will give a positive result with alkaline aqueous iodine so the answer is **C**.

# CHEMISTRY

> **Paper 9701/21**
> **AS Level Structured Questions**

## Key messages

- Candidates should be reminded to read questions carefully and to check answers thoroughly, especially in extended answers where more writing is required.

- The accurate use of chemical terminology is important as it removes ambiguity from responses.

- Candidates should practise applying their knowledge of bonding and structure – key principles in the development of chemical ideas – and of physical processes in particular. Knowledge of organic chemistry beyond the initial study of alkanes and alkenes was an area needing improvement.

- Candidates are reminded that their working in calculations should be shown to ensure that partial credit can be awarded for workings even if the final answer is incorrect.

## General comments

Many candidates achieved a good standard on this paper with marks awarded across the entire range. Good recall of material was shown by some on all topics. Scripts were generally clear and well presented. It should be noted however that it was difficult to read scripts where answers written in pencil have been overwritten in ink and not rubbed out.

## Comments on specific questions

### Question 1

**(a)** There were many correct answers to this question but the majority of answers missed one of the points. A common error was to give the definition of relative atomic mass, rather than relative molecular mass. The word atom (or isotope) was required with reference to carbon-12.

**(b)(i)** This question was well answered by many candidates, though frequent incorrect attempts involved the ideal gas equation. A simple volumetric comparison (applying Avogadro's Law) was sufficient for credit.

**(ii)** This question was also often well answered but some candidates did not calculate the volume of water vapour correctly, and so did not find the stoichiometric ratio for hydrogen.

**(iii)** Many candidates made use of the alternative values of $x = 4$ and $y = 10$, gaining credit despite earlier missing or incorrect answers. A common error using whichever values however, was to forget that the alcohol has an oxygen atom of its own, reducing oxygen's stoichiometric factor by $1/2 O_2$.

**(iv)** Again, many candidates made use of the alternative values of $x = 4$ and $y = 10$. Whilst the naming of the secondary alcohol was usually done well (propan-2-ol, butan-2-ol), candidates often did not show the position of the alcohol group in the primary alcohol's name – gaining no credit for, *e.g.*, propanol, butanol (*cf*. propan-1-ol, butan-1-ol).

**(v)** Many candidates were able to make the necessary calculation, but did not score full credit either because of an error in the conversion of the data to SI units, or because the final answer was not

given to three significant figures. A significant number of candidates used 8.13 as the value of the gas constant $R$.

## Question 2

**(a)**    This question produced a wide variety of responses from candidates. Whilst stronger candidates were able to gain full credit here, a majority of candidates did not answer well.

**(b)(i)**    Most candidates answered this question correctly.

**(ii)**    Many candidates were able to answer this question reasonably well but some answers lacked detail. A number of candidates identified a hydrogen bond as being the interaction between H and O on separate water molecules. The best answers showed the involvement of a lone pair on O, and the existence of a series of partial charges on sequential atoms: $H^{\delta+}$ and $^{\delta-}O—H^{\delta+}$, or $O^{\delta-}$ and $^{\delta+}H—O^{\delta-}$, again on separate molecules.

Candidates needed to show that, unlike in for example, dimeric ethanoic acid, hydrogen bonds in ice are not seen between pairs of molecules. Further, the hydrogen bond will ideally be drawn as roughly linear with the O—H covalent bond, though longer and clearly differentiated.

**(c)(i)**    Whilst many candidates were able to answer this question well, a high proportion of candidates showed insufficient understanding of changes of state, giving answers suggesting that zone **X** corresponded to gaseous copper, zone **Y** liquid, and zone **Z** solid. Answers giving **X** = gas; **Y** = gas & liquid; **Z** = liquid were also accepted.

**(ii)**    Most candidates were able to identify that the energy of particles decreased during cooling. However, fewer could accurately describe their motion as being slower, as opposed to "less", which was not accepted, owing to potential interpretation of displacement rather than speed/velocity.

**(iii)**    This question was the most challenging on the paper. Many candidates confused stage **Y** for a simple cooling period. A large proportion of those who did correctly identify this as the freezing point, gave this or the "latent heat of fusion" as an insufficient justification. The strongest answers provided a statement that bond formation was exothermic, which compensated for the cooling effect of the bulk substance. An alternative answer was accepted for partial credit, which was to identify specifically the loss of (translational/rotational) kinetic energy in the change of state.

## Question 3

**(a)(i)**    This question was answered well by most candidates.

**(ii)**    This question was answered well by most candidates.

**(iii)**    Fewer candidates answered this question correctly compared to **(i)** and **(ii)**. A common wrong answer was **D** (Mg), at the other end of group 2.

**(iv)**    A number of candidates understood *volatile* to mean *reactive*. Therefore many candidates gave **C** as their answer.

**(v)**    This question proved more challenging than the other parts of **Question 3**. There was a range of answers given, with **C** and **G** common incorrect answers.

**(b)(i)**    Only the strongest candidates answered this question correctly. Many incorrect answers referred to the differing reactions of magnesium with water and steam.

**(ii)**    This question was answered well by most candidates but frequently the incorrect use of the word *precipitate* was seen. Candidates are advised to avoid the use of *fumes*, as the state of the suspended particles in this colloid is unclear.

**(iii)**    Many candidates were able to gain full credit here. However a significant minority forgot to balance the equation (requiring **2**$H_2O$), or gave the wrong state symbols. $H_2O$ is (l).

A common error was to recall the wrong reaction of Mg with $H_2O$ – that of steam – which gives a simpler equation. Candidates were awarded credit for state symbols only in this case.

**(c) (i)** A large number of candidates were unable to answer this question that asked them to recall the thermal decomposition of $Mg(NO_3)_2$.

**(ii)** More candidates were able to give the equation for the slaking of lime compared to the thermal decomposition of limestone, for which $O_2$ was often given as a product.

**(d) (i)** There were many good answers to this question. Some candidates showed confusion over the direction of the pH scale suggesting that both pH and acidity decreases.

**(ii)** This question was answered well by only a small number of candidates. Candidates who attempted to give an ionic equation sometimes made errors over the correct charge of carbonate, $CO_3^{2-}$, or the stoichiometry of the equation (including **2**$H^+$).

Although $Ca^{2+}$ cannot be considered a spectator ion as it shows a change of state, candidates who gave $CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2$ were given credit.

**Question 4**

**(a) (i)** This question was answered well by most candidates.

**(ii)** This question proved challenging for the majority of candidates. Stronger candidates gave statements in both parts of the question that explained *hybridisation*, and gave details of the number and type of orbitals involved. Partial credit was given if candidates managed to mention a mixing effect (owtte), or to identify the involvement of s and p atomic orbitals.

**(iii)** There were many good answers to this question and partial credit was given if candidates had reversed their answers. A range of values for the bond angles were allowed, as a result of the irregularity of *e.g.* $CH_2Cl_2$ (H$\hat{C}$H = 112.0°) and $H_2C=CH_2$ (H$\hat{C}$H = 117.3°).

**(b) (i)** Many candidates were clearly aware of the need to show an expanded structure of **R**, but unfortunately did not display the O—H bond.

**(ii)** There were many good answers to this question.

**(iii)** There were a number of good answers to this question but many candidates added HBr to the double bond rather than $Br_2$. Credit was given if the bromohydrin product was shown, a result of the addition of $Br^+$ (from $Br_2$) followed by $OH^-$ (from $H_2O$).

**(iv)** This question was answered well by most candidates.

**(c) (i)** Candidates showed that they were aware of the chemistry here but the majority gave insufficient or partially incorrect answers. Common errors included 'aldehyde / ketone' rather than the named compounds, and 'propan-1-al' (not the IUPAC accepted naming). Some credit was given if candidates had reversed their answers.

**(ii)** There were many good answers to this question.

**(d) (i)** Candidates needed to give more than one creditable statement in order to obtain full credit. Although some very good and comprehensive answers were seen from stronger candidates, many candidates were not able to give more than one statement.

**(ii)** An accurate representation of the mechanism, showing the correct location of lone pairs and dipoles was required here. Curly arrows should have clearly started at the lone pair of :$CN^-$, —$O^-$ or the $C=O$ bond. The structure of the high-energy intermediate was not required.

# CHEMISTRY

| Paper 9701/22 |
| AS Level Structured Questions |

### Key messages

- Candidates are advised to look at the number of marks allocated to a specific question. This information indicates the level of detail which needs to be included in a response.

- Candidates should be reminded to take time to read all the information provided in questions particularly when approaching analytical or qualitative problems.

- Candidates should check any chemical equations are correctly balanced.

### General comments

Stronger candidates gave clear, accurate presentation of information using appropriate chemical terminology and logical progression of argument and demonstrated a good knowledge and understanding of the subject.

Care needed to be taken when giving definitions or explanations to make sure that appropriate vocabulary was used. For example candidates were expected to use the terms *atoms*, *ions* and *molecules* in the appropriate context. Questions which required identification of compounds using only correct names were answered correctly in fewer responses than questions which required any form of chemical identification.

### Comments on specific questions

### Question 1

**(a)** The majority of answers correctly described the nucleon number, number of protons and number of neutrons of the lithium ion. Although many candidates correctly gave the atomic number and the nucleon number of the species in the second line, use of the correct symbol was not always seen. Some answers did not identify the correct symbol or the +3 charge on the iron ion. Others gave the relative atomic mass of iron, quoted from the Periodic Table, rather than reference to the information in the question which related to a specific ion.

**(b)(i)** This definition was well known. However, some responses were confused and described the comparison of an atom with 12 g of a carbon-12 isotope.

**(ii)** Many answers demonstrated correct calculations of the relative isotopic mass of the boron-11 isotope using the relative atomic mass, given in the Periodic Table, and gave the answer to six significant figures as required. Only a small number of answers gave an incorrect number of significant figures. Some candidates did not understand that the relative atomic mass shown in the Periodic Table was required to calculate the relative isotopic mass and attempted to answer the question using only the data in the question.

### Question 2

**(a)** Identification of the strong triple bond to explain the unreactivity of nitrogen was common but a much smaller number of answers included the idea that it was a non-polar molecule.

**(b)(i)** Many answers described the heat energy or high temperature produced in a car engine as sufficient to break the bonds between nitrogen molecules allowing the nitrogen and oxygen from the air to react.

**(ii)** The majority of candidates understood that either a catalyst was responsible for the reaction or that the removal of the oxides of nitrogen involved a reduction reaction but few linked the two ideas together. Although many answers gave equations showing correct reactants and products, it was common to see these equations incorrectly balanced, particularly when describing the amount of nitrogen gas produced.

**(iii)** Many answers described the role of nitrogen dioxide as a catalyst and described two correct equations which related to the formation of acid rain either by looking at the catalytic action of nitrogen dioxide or by showing how the sulfur trioxide made is converted into acid rain. Some answers however, did not focus on how nitrogen dioxide contributed to the formation of acid rain by oxides of sulfur and instead they attempted to show how nitrogen dioxide contributed directly to acid rain formation.

**(iv)** Few candidates correctly identified the reactants involved in the formation of acid rain directly from nitrogen dioxide and then balanced the equation correctly.

**(c)** The explanations of how the uncontrolled use of fertiliser on land caused a reduction in the water quality in rivers were generally good. Many answers correctly described how the fertiliser found its way into rivers and described the deterioration in water quality in terms of a fall in the amount of dissolved oxygen. However, there was some confusion regarding the details of the process involved. The promotion of plant and algal growth was rarely discussed and bacterial decomposition was not well understood. There were some answers which incorrectly described the action of the fertilisers causing a chemical reduction of water molecules.

**Question 3**

**(a)** The majority of answers given were correct: $(+)103 \, kJ \, mol^{-1}$. Common incorrect answers described the enthalpy change for the formation of hydrogen bromide rather than its decomposition.

**(b)(i)** The quality of the curves showing the Boltzmann distribution at a higher temperature varied. Answers which showed that the curve started at the origin and gave the same general shape of the curve displaced to the right, gained partial credit. Better responses drew a curve with a peak lower than the original and crossing the original curve once only. A common error was to show the tail end of the curve meeting or crossing below the original at energy values greater than the activation energy.

**(ii)** Only the strongest candidates attempted to explain the effect of increasing temperature on the rate of decomposition with reference to the two curves. The majority of answers correctly explained the increase in rate of reaction which occurs due to the increasing number of collisions between reacting particles and that more of the colliding particles had energies greater than the activation energy. A small number of very strong answers described the increased frequency of successful collisions. There were some confused answers that attempted to introduce equilibria arguments.

**(iii)** Many answers showed a good understanding of the effect of increasing temperature on the percentage of hydrogen bromide which decomposes and attempted to explain the effect in terms of le Chatelier's principle. The idea of the equilibrium shifting in the forward direction was described in many responses but it was less common to see answers which attempted to explain why this occurred in terms of opposing the change which had been imposed on the equilibrium reaction. Some weaker responses stated that the equilibrium would shift in the reverse direction.

**(iv)** Many answers explained the difference in the percentage of hydrogen iodide which decomposed compared to hydrogen bromide in terms of a comparison of bond strength. This idea was often correctly related to the change in size of the halogen atom. Weaker responses incorrectly referred to the size of the halide ions. Only stronger answers went on to explain that the hydrogen-halide bond strength is smaller in hydrogen bromide because the nucleus of bromine has a greater attraction for the bonding pair of electrons or gave an explanation in terms of a greater proportion of orbital overlap between bromine and hydrogen.

**(c) (i)** Many responses correctly calculated the amounts of hydrogen and hydrogen chloride present in the equilibrium mixture. A common error was to ignore the stoichiometry of the equation when working out the amount of hydrogen chloride in the equilibrium mixture.

**(ii)** A significant number of answers correctly used the values produced in **(i)** to calculate the mole fractions of each gas in the equilibrium mixture.

**(d) (i)** An expression for $K_p$ should use the species involved in the reaction and should not use specific values which would be used to calculate a specific $K_p$ value. Weaker responses either ignored the use of partial pressures when expressing $K_p$ and gave the expression in terms of concentrations or gave expressions using both partial pressures and concentrations. Occasionally the value of $K_p$ was shown for the reverse reaction.

**(ii)** This question proved challenging for many candidates. Stronger responses explained that the total pressure of the system is not required as this value cancels out because there are equal amounts of gas present on either side of the equation. A common incorrect answer suggested that the partial pressure values cancelled out.

**(iii)** Many responses showed correct use of the data provided and the expression for $K_p$ from **(i)** to calculate the value for $K_p$.

**Question 4**

**(a) (i)** The skeletal formula of butane was described correctly in the majority of responses. Incorrect answers were rare and tended to show skeletal representations with the incorrect number of carbon atoms in the chain.

**(ii)** This question was generally well answered. Weaker responses attempted to explain the difference in boiling points in terms of the strength of the intramolecular (covalent) bonds rather than the strength of the intermolecular induced dipole forces of attraction. There were many clear, accurate answers which correctly accounted for the difference in boiling point in terms of the strength of the induced dipole attractions and gave an explanation which accounted for this difference in terms of the increased surface area of straight chain molecules.

**(iii)** Many responses correctly identified the structural formula of **B** by using all the information provided in the question.

**(iv)** Candidates needed to apply their knowledge of the definition of geometric isomerism to explain why but-2-ene can show this type of isomerism. Key to this is the idea that each carbon of the double bond is bonded to two different groups and that the carbon-carbon double bond is unable to rotate (or has limited rotation). Many answers attempted to describe the first point but the second was seen only occasionally.

**(v)** Many responses describing the mechanism in **(a)(v)** and **(vi)** gave the impression that the pattern of the curly arrows and dipoles has been learnt without fully appreciating what these symbols represent. Ambiguity was frequently seen regarding the origin and destination of the pair of electrons from a bond or a lone pair which is represented by the curly arrows. The double bond of the alkene was frequently shown incorrectly with a $\delta-$ charge and incorrect orientation of the partial charges on the dipole of the bromine molecule was also seen.

**(vi)** This question proved challenging. Only stronger candidates showed an understanding of the origin of the dipole in the non-polar bromine molecule in terms of the induction of the dipole by the proximity of the electron rich area of the C=C double bond.

**(b) (i)** Identification of **C**, **D** and **E** using correct names or any non-ambiguous structure was credited. Occasionally correct structures were accompanied by incorrect names. Full credit here was given to responses which had used all the information given in the question including the idea that both isomers **D** and **E** were branched. This idea was missed in many responses. Some answers showed confusion when identifying the structure of **C** as a tertiary alcohol.

**(ii)** Many answers did not show the correct formula of sodium carbonate. Even when the correct formula of sodium carbonate was used, the equations were not always balanced. Some responses used sodium hydrogen carbonate in the equation in spite of the question asking for the equation for the reaction of **E** with sodium carbonate.

**(c)(i)** Very few responses gave the correct *name* of the product formed during the reaction. Many identified the formula of the product, $CHI_3$, which was not awarded credit.

**(ii)** Candidates needed to apply their knowledge of the reactions of carbonyl compounds to the relevant information given regarding compounds **F** and **G** in order to describe their structural formula. Many responses showed that **F** was a ketone but did not use the positive test result of the reaction of alkaline aqueous iodine. $CH_3CH_2COCH_2CH_3$ was commonly given rather than $CH_3CH_2CH_2COCH_3$. Many answers correctly identified **G** as an aldehyde but did not use the information that molecules of **G** contained a chiral centre and that it did not react with alkaline aqueous iodine. $CH_3CH_2CH_2CH_2CHO$ was seen rather than $C_2H_5CH(CH_3)CHO$.
Only a small number of candidates incorrectly represented the aldehyde group as COH.

**(iii)** The idea that there are four different *molecules* attached to a central carbon atom was a common incorrect answer and illustrated how important it is for appropriate chemical vocabulary to be used in the correct context.

**(d)(i)** Good answers correctly identified the specific bond responsible for a particular absorption peak when analysing the infra-red spectra. Weaker answers referred to the presence of specific functional groups.

**(ii)** A small number of responses were seen which used the information given in **(d)(i)** and the molecular formula to correctly name **H** and **I**. However, responses which correctly named possible structures of **H** and **I** from the molecular formula given in the question were also credited. Identification of compounds using their correct names proved challenging for many candidates.

# CHEMISTRY

## Key messages

• Candidates are advised to look at the number of marks allocated to a specific question. This information indicates the level of detail which needs to be included in a response.

• Candidates should be reminded to take time to read all the information provided in questions particularly when approaching analytical or qualitative problems.

• Candidates should check any chemical equations are correctly balanced.

## General comments

Significant figures appeared challenging for a significant number of candidates who either did not read the question or were unfamiliar with the principal of determining significant figures.

Candidates should take particular care with mathematical questions; expressions with correct values were often given, but the final answer(s) for these expressions were frequently incorrect because of incorrect transcription of numbers.

## Comments on specific questions

### Question 1

**(a)(i)** Many full-credit answers were seen; the key statements requiring same molecular formula and different structural formulae were not always precise and accurate. Reference to empirical formula and spatial arrangements were often included in answers.

**(b)(i)** This question was not well answered. Many answers used the volume of $150\,cm^3$ to calculate the value of x and did not appreciate that this volume contained both $CO_2$ and excess oxygen. There were a number of answers that included attempts to use the general gas equation.

**(ii)** This question proved equally challenging; many candidates attempted to substitute values for *x* and *y* into the $\left( x + \dfrac{y}{4} \right)$ expression instead of using a ratio of the values given in the question.

**(iii)** Many correct answers were seen with candidates using answers from **(i)** and **(ii)** or the values given in the stem of this question.

A number of candidates were unable to calculate a correct empirical formula from their molecular formula.

**(iv)** Many candidates answered this question well; a number of candidates gave structural formulae instead of skeletal. The requirement for unbranched isomers was missed by a few candidates. Several answers gave saturated hydrocarbons that did not match the molecular formula.

**(v)** There were many correct answers to this part. Incorrect answers included volumes given in $dm^3$, pressures in kPa and incorrect significant figures.

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**Question 2**

**(a) (i)**  The physical states of the halogens, at room temperature, were quite well known and there were many good answers.

The answers to the colour of the halogens were varied with the most common error being purple, or blue/black for iodine.

**(ii)**  Several full-credit answers were seen; the two themes of increasing number of electrons, down the group, accompanied by increased named intermolecular forces of attraction, needed to be mentioned.

A small number of answers incorrectly referred to the breaking of 'covalent bonds' and confused 'volatility' with 'thermal stability' and 'chemical reactivity'.

**(b)**  There were many correct answers referring to the 'decrease in oxidising power of the halogens, down the group', associated with 'increased shielding' or 'increased distance of the outer shell from the nucleus'. The most common mistake was to confuse the concept of 'electronegativity', involving the attraction of electrons, with the ability to 'accept' electrons, and, hence, behave as an oxidising agent.

**(c) (i)**  This question was quite well answered with most answers containing one or more correct observations.

**(ii)**  Examiners were specifically looking for some reference to the redox behaviour of the $H_2SO_4$, with the chloride and iodide, or the increased ability of the iodide to reduce the $H_2SO_4$, compared to the chloride.

**(iii)**  Generally this question was not well answered and balanced equations involving the formation of $Br_2$ and $SO_2$ were rarely correctly mentioned.

Equations forming HBr were frequently correct, but were not followed by any further equation(s) to support the requirement, from the stem, for the formation of brown fumes and an acidic gas that decolourised acidified $KMnO_4(VII)$ solution.

**(d) (i)**  This part was well answered by many, though a common error was to describe what reaction had occurred but to not mention, specifically, that $AgI$, was responsible for the yellow precipitate.

**(ii)**  Some good answers were seen here, though several candidates were not familiar with the solubilities of the silver halides in ammonia solution.

**Question 3**

**(a) (i)**  This question was well answered by most.

**(ii)**  The application of Hess' Law to this enthalpy calculation proved challenging for many candidates.

The most common errors were Hess Cycles where the enthalpy change of formation of $SO_2$ was not doubled and/or the calculated enthalpy change of formation of $SO_3(g)$ was not halved.

**(b) (i)**  This question was correctly answered by many candidates.

**(ii)**  Several candidates gave a definition of a catalyst without mentioning that it provided an alternative pathway; surprisingly few answers stated that the rate of reaction increased, in the presence of a catalyst.

Many answers stated that there were 'more molecules with sufficient energy to react', but did not appreciate that this 'sufficient energy' is known as the $Ea$.

**(iii)**  This question was quite well answered by most candidates with the most common omission being the relating of 'successful collisions' to a specific/unit time, for the increase in rate, when the pressure is increased.

**(c) (i)** This question was well answered by many.

**(ii)** This part was not well answered with the most common error being an incorrect total moles value for the equilibrium mixture. A significant number of answers gave a correct expression for the partial pressure of oxygen but gave incorrect final answers from their calculations.

**(d) (i)** A significant number of answers contained the square bracket annotations for concentration, in addition to the annotation for partial pressures in the expression for $K_p$. A further common error included omission of squared values for $SO_2$ and $SO_3$.

**(ii)** Full credit was awarded for many $K_p$ calculations with correct units. There were a number of candidates who either did not use the values for partial pressures, given in the stem, or did not calculate the values that were inserted into their $K_p$ expression.

**Question 4**

**(a)** There were many correct answers to this part.

**(b)** This question was correctly answered by many candidates; the most common error being an incorrect structure for methylpropene.

**(c) (i)** Examiners were specifically looking for the definition of geometrical isomerism with some reference to a C=C. Many answers were focused on the restricted rotation of the C=C and differing structural formula.

**(ii)** Many answers incorrectly showed polarity on the C=C and carbocation. Curly arrows from atoms, were regularly seen, rather than from covalent bond(s) or lone pairs of electrons.

**(d) (i)** Many candidates were able to give correct answers to this part. A common error was to include the chiral atom being joined to different molecules.

**(ii)** This question was correctly answered by many candidates.

**(iii)** There was a reasonably high omission rate for this question, though it was well answered by many. Several answers contained good three-dimensional diagrams for 2-bromobutane.

**(iv)** This question was not well answered. A common error was to refer to the increased stability of the secondary halogenoalkane rather than the secondary carbocation. A further common error was to incorrectly quote Markovnikov's rule.

**(e) (i)** There were many correct answers to this part.

**(ii)** Many candidates answered this part correctly, but those that named **C** incorrectly in **(i)** tended to give incorrect straight chain isomers here. Candidates needed to understand the reaction of **C** with HBr in order to draw the correct isomers.

# CHEMISTRY

## Key messages

- Candidates should be encouraged to read all the information given in a question as this is pertinent to providing full, correct answers.
- Candidates should be encouraged to record their results in a way in which the headings are clear and accurate and that units are always included.
- Candidates should be careful, when describing the observation in qualitative analysis tests, to state clearly whether a precipitate or a solution is formed and to test for the identity of any gas produced.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

## General comments

The examiners thank Supervisors at Centres who supplied experimental data for **Questions 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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- a copy of the examination paper with the Supervisor's experimental results.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results to ensure that candidate results can be cross checked against the Supervisor's experimental results.

This paper proved accessible to most candidates. Almost all candidates completed the paper indicating that there were no time constraints.

## Comments on specific questions

### Question 1

**(a)** Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to 0.05 cm$^3$. Candidates recording two titres within 0.10 cm$^3$ should be encouraged to continue with the rest of the paper, rather than performing a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

**(b)** The majority of candidates calculated a suitable value for the volume of **FA 4** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

**(c)** There were many good answers to this section. However, while the majority of candidates gained credit for parts **(i), (ii), (iii)** and **(iv)** a significant number of candidates did not recognise that in **(v)** it was necessary to multiply the number of moles of $Cu^{2+}$ by 40 before dividing this number into 26.0.

## Question 2

**(a)** Candidates should be encouraged to read through practical instructions completely before handling apparatus so they are able to record all the data stipulated clearly. The most common errors were to write incorrect or ambiguous headings and to confuse the mass of residue with the mass lost when **FA 5** was heated. If, for example, a heading includes a lid in one weighing, the lid must then be specified in all subsequent relevant weighings.

**(b)(i)** Most candidates correctly calculated the number of moles of copper oxide from the mass of residue.

**(ii)(iii)** Although most candidates showed that they knew the basic method for the conversion of masses and moles, a significant number did not divide the number of moles of copper oxide by 2 when calculating the number of moles of malachite/ $M_r$ of malachite.

**(iv)** The vast majority of candidates calculated the $M_r$ correctly.

**(v)** Answers correctly based on candidates' results were allowed, even if these values were not actually correct. For full credit however it was necessary to actually state whether the values supported the accepted formula.

**(c)(i)** A number of suggestions were acceptable but the improvement and reason for the improvement had to be precisely explained. Candidates that stated that the crucible should be heated for longer, needed to provide a reason for this. Since both water and carbon dioxide are released in this decomposition, it was also incorrect to explain the improvement as ensuring that all the **water** was released.

**(ii)** Although a number of answers recognised that the significant difference between **Experiments 1** and **2** was the mass of solid used, for credit to be awarded this had to be linked to the lower **percentage** error that this caused.

## Question 3

**(a)** A number of observations were acceptable and all these were seen in responses, although comparatively few candidates gave the three observations required for the award of full credit. Although the formation of a gas was clearly recognised by many, few tested for the production of oxygen. However the release of the brown gas during the composition led many candidates to correctly suggest the identity of **FA 6**. Either $Cu(NO_2)_2$ or $Cu(NO_3)_2$ was accepted.

**(b)(i)(ii)** Correct observations for all tests were seen but candidates should be advised of the importance of specifying whether a solution or a precipitate is formed in a reaction and of stating an appropriate colour change in either case. Here, for example, the iodine produced in the potassium iodide test cannot be described as red and the final solution produced in the reaction of ammonia with **FA 6** must be described as **dark** blue.

The test with magnesium proved the most challenging with few candidates giving an acceptable observation for the reaction with **FA 6** or actually testing for the formation of hydrogen in the addition to **FA 7**. This effervescence however led to a significant number correctly deducing the presence of an acid.

**(iii)** A correct ionic equation was given by a relatively small number of candidates.

**(iv)** This also proved challenging since many candidates, presumably having seen red/ brown colours in the observations, suggested that the reaction was a displacement.

**(v)(vi)** These also proved challenging. In **(v)** many responses were based on adding ammonia, although this was not included in the tests actually carried out, and in **(vi)** very few linked the formation of the precipitate they had observed in the test with ammonia to the problem of using this reagent to see whether a silver halide precipitate dissolved.

# CHEMISTRY

> **Paper 9701/32**
> **Advanced Practical Skills**

## Key messages

- Candidates should be encouraged to record their results in a way in which the headings are clear and accurate and that units are always included.
- When recording results candidates should ensure that these are stated to an appropriate number of significant figures.
- Candidates should be careful, when describing the observation in qualitative analysis tests, to state clearly whether a precipitate or a solution is formed, to accurately describe the colour of the solution/precipitate and to test for the identity of any gas produced.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

## General comments

The examiners thank Supervisors at Centres who supplied experimental data for **Questions 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results to ensure that candidate results can be cross checked against the Supervisor's experimental results.

This paper proved accessible to most candidates. Almost all candidates completed all questions indicating that candidates had sufficient time to complete the paper.

## Comments on specific questions

### Question 1

**(a)** Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to 0.05 cm$^3$. Candidates recording two titres within 0.10 cm$^3$ should be encouraged to continue with the rest of the paper, rather than performing a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

**(b)** The majority of candidates calculated a suitable value for the volume of **FB 1** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

**(c)** There were many good responses to this section, showing that candidates generally understood the relationship of moles, concentrations, masses and volumes. This meant that many correct answers were seen for parts **(i), (ii)** and **(iii).**

Whilst the identification of the anion in **(iv)** was allowed, following any value calculated in **(iii),** very few correct answers were seen. Many candidates gave the formula of the acid, rather than the

anion A⁻, and a significant number suggested a single element or the nearest halogen by comparing the $M_r$ of HA with the values given in the Periodic Table.

**(d)(i)** This part proved challenging with few candidates realising that, if the sodium hydroxide was less concentrated the titre would be less and therefore the calculated $M_r$ would also be less.

**(ii)** This also proved challenging since a precise explanation was needed. It was, for example, insufficient merely to say that another acid would have been identified.

## Question 2

**(a)** Candidates should be encouraged to read through practical instructions completely before handling apparatus so they are able to record all the data stipulated clearly. The most common errors were to omit the average initial temperatures or not to record the temperatures to the nearest $0.5\,^\circ$C.

The temperature rises in both **Experiments 1** and **2** should have been the same and most candidates gained at least partial credit for accuracy here.

**(b)(i)** Most candidates correctly calculated the number of moles of both acid and alkali.

**(ii), (iii) and (iv)**
Most candidates were clearly familiar with the use of the formula energy change = $mc\Delta T$ and then the division by the number of moles involved in the reaction. A number however did not recognise that 50 cm³ of solution were involved in **Experiment 1** (and 100 cm³ in **Experiment 2**) or that the limiting factor was the number of moles of alkali.

**(v)** To be awarded credit, the final answers for the molar energy and enthalpy changes had to be quoted to an appropriate number of significant figures (2 to 4) and the negative signs for the final enthalpy changes had to be given. Most candidates gained credit here.

**(c)(i)** Many candidates correctly calculated the maximum percentage error in the volume of **FB 3** but very few calculated this for **FB 4**. The most common error was to divide by 2 rather than multiplying by 2.

**(ii)** Many correct answers were seen, although simply stating that heat loss should be reduced without specifying exactly how, was not acceptable.

## Question 3

**(a)(i)** A variety of acceptable answers were seen but, to gain credit, the conclusion had to follow a correct observation and the strong/ weak acid had to be clearly identified. Some answers, such as 'see which one is dissociated less', were not based on any possible practical observation.

**(ii)** A number of candidates observed the effervescence produced when **FB 7** was heated with sodium hydroxide and aluminium but did not attempt to identify the gas. Others appeared confused by the instruction to write 'not needed' if a test was unnecessary. If the presence of nitrate had been found in the sodium hydroxide/aluminium test it was not necessary to carry out the test with barium ions.

**(b)** In completing the table of observations it was essential to include precise descriptions of the formation (or not) of precipitates and also the colours involved in any reactions. This was particularly significant when, as in this case, some of the tests were not ones with which it was expected that the candidates will be familiar.

**(i)**    A blue precipitate was expected although any shade of blue (apart from dark) was accepted.

**(ii)**    Since both iodine and copper(I) iodide are formed any shade of yellow/ brown was accepted but this mixture cannot reasonably be described as orange or red.

**(iii), (iv)**    The colour changes should have been blue to more green in **(iii)** and then back to blue in **(iv)**. No precipitate is formed in either reaction.

**(v)**    The final solution, with excess ammonia, must be stated as being **dark** blue.  This is a reaction with which candidates should be familiar.

**(vi)**    This reaction however, using edta, was not one which  many candidates would have seen so any answer that suggested that the colour was darker blue was accepted.

**(vii)**    Presumably, since blue solutions and precipitates had been observed, many candidates recognised the presence of copper.  To gain credit, since the question asked that the **cation** should be identified, it was necessary to include the oxidation state.

**(viii)**    Few candidates wrote an acceptable ionic equation.  A significant number attempted to use the reaction in **(ii)** but gave incorrect products.

# CHEMISTRY

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| **Paper 9701/33**                   |
| **Advanced Practical Skills 1**     |
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## Key messages

- Candidates should be reminded to read all the information given in a question to ensure they produce full, correct answers.

- Candidates should be encouraged to tabulate their results ensuring there is no repetition of headings and that units are always included.

- Candidates should understand the meaning of "precipitate" and appreciate that "precipitate formed" is not a valid comment when adding a solid to a solution.

- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the question paper.

## General comments

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results to ensure that candidate results can be cross checked against the Supervisor's experimental results.

This paper proved accessible to most candidates. Almost all candidates completed all questions indicating that candidates had sufficient time to complete the paper.

## Comments on specific questions

### Question 1

**(a)** Almost all candidates recorded the two balance readings and mass of **FA 2**, but fewer recorded their burette readings for the rough titre. Some candidates did not appear to know how to record accurate burette readings to $0.05\,cm^3$ or to go on to the next part of the question once two concordant titres have been achieved. However, many candidates completed the titration successfully with all data clearly presented and most gained credit for accuracy.

**(b)** The majority of candidates calculated a suitable value for the volume of **FA 1** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to two decimal places.

**(c)** Most candidates correctly calculated the number of moles of sulfuric acid in **(i)** and successfully balanced and used the equation in **(ii)** to find the number of moles of sodium hydrogencarbonate pipetted into the conical flask in **(iii)**. Only stronger candidates calculated the mass of sodium hydrogencarbonate correctly in **(iv)**. Most candidates omitted the factor of 10 which was needed to fully answer the question. Part **(v)** was challenging for some candidates as incorrect working was

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given to produce an answer closer to that expected. Candidates should note that the number of significant figures to be used reflects the accuracy with which the solutions have been prepared and the accuracy of the apparatus used. All answers in these parts should have been displayed to three or four significant figures. A minority of candidates answered **(vi)** correctly with the majority commenting on the proportion of impurity present which was not a valid response to the question. Most candidates gained credit for the percentage error in **(vii)**. The most common error was to multiply the error given on the flask by a factor of two.

**Question 2**

**(a)**     Candidates should be encouraged to read through all of the practical instructions completely before handling apparatus so they are able to record all the required data clearly. The most common errors were to write incorrect or vague headings and to record the mass lost rather than the mass of residue, **FA 5**.

**(b)**     Many candidates chose to use the 95.8% given in the paper in **(i)** especially if their answer in **1(c)(v)** was low. Most candidates went on to gain the credit for **(i)** and **(ii)**. Fewer answered **(iii)** correctly, especially where the correct calculation gave a negative mass as the answer. A range of errors was seen. However, many used their answers in **(i)** and **(iii)** correctly to answer **(iv)**. Candidates using the information given in the Periodic Table generally answered **(v)** well but a significant proportion did not provide any calculated evidence for their answers.

**(c)**     Only the strongest candidates answered **(i)** well with few mentioning both water vapour and absorption by the residue. The most frequently seen incorrect answers involved the use of a lid to prevent substances escaping or to prevent air from entering the crucible. The second part of the question, **(ii)**, was also challenging for candidates from some Centres. While many suggested repeating the experiment and taking an average of the results, there was little mention of concordance or of discarding anomalous results before averaging. The answers involving using a larger mass of **FA 4** or cooling the product in a desiccator generally gained credit.

**(d)**     Candidates should be reminded that, if a question requires "all your observations" to be recorded, credit will generally only be awarded if there is more than one correct observation. Candidates should be aware that adding a solid to a solution does not indicate the formation of a precipitate. Many more candidates gained credit in **(ii)** as they either used their observation(s) in **(i)** or went on to describe a successful limewater test as evidence for $CO_3^{2-}$. Few candidates recorded $Na_2CO_3$ in **(iii)** and even fewer gave the correct state symbol. The most frequently seen incorrect answers involved NaOH and $Na_2O$. While there were some excellent answers from stronger candidates, weaker candidates found these questions challenging due to the level of difficulty increasing because of the 2:1 mole ratio.

**Question 3**

**(a)**     Candidates generally answered **(i)** correctly giving the reactions with aqueous barium ions followed by dilute nitric acid and for silver nitrate. However, there were candidates who wrote "no observation" or "–" instead of "no visible reaction" or who recorded "white solution" instead of "white ppt". Some candidates could not be credited for the observations on adding silver nitrate as they went on to add aqueous ammonia to the mixture. Few candidates gained credit for adding solid sodium carbonate as most reported a white precipitate instead of realising they had added excess solid. Stronger candidates gained credit in **(ii)** but the significance of effervescence with sodium carbonate was mentioned infrequently or **FA 7** was deemed more acidic as it contained sulfate or **FA 6** was stated to have the lower pH.

**(b)**     The standard of answers in **(b)** was higher than in **(a)** as the Qualitative Analysis Notes gave more guidance. Almost all candidates chose to use aqueous sodium hydroxide and aqueous ammonia as their reagents and carried out the tests successfully. The most common error was to describe the precipitate formed with **FA 6** as being brown and then to conclude the cation was $Fe^{3+}$.

**(c)**     Many gained full credit in this question. However, a number of candidates only gave the formulae of the cations present in **FA 6** and **FA 7** instead of incorporating their results from **(a)**.

# CHEMISTRY

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| Paper 9701/34 |
| Advanced Practical Skills 2 |

### Key messages

- Candidates need to understand the level of precision of apparatus as well as masses, volumes or concentrations of reactants and how this relates to appropriate numbers of significant figures in calculations.

- Candidates should be reminded to produce graphs with suitable scales and to construct and extrapolate appropriate lines of best fit. Anomalous points must be clearly indicated.

- Candidates should be encouraged to tabulate their results ensuring there is no repetition of headings and that units are always included.

- Candidates should understand the meaning of "precipitate" and appreciate that "precipitate formed" is not a valid comment when adding a solid to a solution.

- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the question paper.

### General comments

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This paper proved accessible to most candidates. Almost all candidates completed all questions indicating that candidates had sufficient time to complete the paper.

### Comments on specific questions

### Question 1

**(a)**     A number of candidates did not record their thermometer readings to the nearest 0.5°C. A few either did not record the mass of magnesium or mistakenly recorded it in the body of the instructions. The majority of candidates scored at least partial credit for accuracy in this part.

**(b)**     Only the strongest candidates plotted and drew graphs of a suitable standard. Common errors included too little of the *y*-axis being used, not allowing for a 10°C extension and labelling the *x*-axis time /s without converting the times given in **(a)** which were in minutes. A few candidates did not plot the initial temperature or the temperatures between that at three minutes and the maximum, and those using difficult scales usually incorrectly plotted some points. Many candidates made poor choices for the lines of best fit. The cooling line should either have shown points equally distant in total on each side of the line or have been very close to the maximum thermometer reading and the subsequent four points. Few candidates drew a curve even when this would have fitted the points

better. Most candidates extrapolated their lines but some omitted or misplaced the vertical at 2½ minutes. The majority of candidates read the temperature values from the graph correctly though some recorded the highest temperature rather than the rise in temperature as instructed.

**(c)** Most candidates answered **(i)** well. The most common mistake was in using the mass of solid rather than 25 cm$^3$ or recording the answer to five significant figures. In **(ii)** most candidates successfully calculated the number of moles of magnesium which reacted and went on to show appropriate working for the final answer, giving the correct sign for the exothermic reaction. However, some ignored the instructions and used a factor of two to calculate the enthalpy change per mole of ethanoic acid.

**(d)** A small number of candidates used only one piece of magnesium ribbon. Many did not record the rise in temperature as instructed. A few candidates recorded thermometer readings every 1/2 minute as in **(a)**, contrary to the instructions given. At some Centres using 1 dp balances it was not possible to compare $\Delta T$/m ratios and therefore it was especially important that the lengths were as stipulated in the Confidential Instructions.

**(e)** The majority of candidates gained full credit. Some candidates who had made errors in **(c)** corrected them in this part.

**(f)** Many candidates did not explain their choice of answer sufficiently in **(i)**. Successful candidates usually answered in terms of a faster reaction losing less heat energy to the surroundings. While a substantial minority stated that only the activation energy would be lowered, fewer related this to the practical exercise, namely that neither $\Delta T$ nor $\Delta H$ would be changed. Only a small number of candidates remembered the earlier statements that the acids were in excess so few gained credit in **(ii)**. Most candidates answered in terms of strength of acid or concentration of hydrogen ions.

**(g)** The writing of an ionic equation in **(i)** proved challenging for many candidates. A common error was to include the chloride ion, either as H$Cl$ or C$l^-$ or to start with Mg$^{2+}$. Some omitted state symbols and a few did not balance the equation. Even fewer candidates gained full credit in **(ii)**.

**(h)** The majority of candidates rewrote the information given in the question. Some candidates wrote about the difference in ionisation but did not link this to the concentration of H$^+$(aq). Those who were successful in **(i)** tended to give the same answer in **(ii)** which was not credited. A common error was to state that less energy is produced in the reaction with the weaker acid. As the energy produced by H$^+$(aq) + OH$^-$(aq) is the same for all acids, reference was needed to the energy required to break the O–H bond in the carboxylic acid.

## Question 2

**(a) (i)** Most candidates gained at least partial credit here. However, few tested the gas evolved on adding sodium carbonate with limewater. Some candidates incorrectly reported "no observation" instead of "no visible reaction" or "colourless solution" for "no ppt formed" or "ppt dissolved".

**(ii)** Only a minority of candidates correctly identified H$^+$ as the cation even though almost all correctly reported effervescence with sodium carbonate in **(i)**. The most common incorrect answer was NH$_4^+$ and a range of other cations was suggested by some candidates.

**(iii)** Despite the extensive use of magnesium in the previous question, some of those candidates identifying H$^+$ in **(ii)** did not suggest its use here. Although candidates were told to carry out their test it was evident from the results that some did not do so. As aqueous ammonium salts of strong acids are acidic, the test for the ammonium ion was allowed. However, almost all claiming its presence in **(ii)** reported red litmus turning blue which would not have occurred had the test been carried out correctly.

**(iv)** Almost all candidates gained at least partial credit with the majority gaining full credit for the identification of the anions.

**(v)** The candidates who answered correctly tended to use the Devarda's test and only a few gave a named acid and reported no brown gas evolved. Weaker candidates often used OH$^-$ in place of NaOH, omitted that the mixture should be heated, or did not stipulate that it is the gas which is tested with damp red litmus paper.

**(b)** Most candidates gained at least partial credit here. The most frequently seen errors were missing the bubbling on adding hydrochloric acid to **FB 8**, describing the colour of solution on adding hydrogen peroxide inappropriately or reporting the formation of a precipitate. Most candidates gained credit for no visible reaction with aqueous sodium hydroxide. The omission of "precipitate" or an incorrect description of colour caused candidates problems in the next three tests. Many reported that **FB 8** contained the iodide ion but fewer correctly identified the carbonate ion even though some reported a positive limewater test in the first section. Several cations were suggested by a significant number of candidates – these included $NH_4^+$, $Fe^{3+}$ and $Cr^{3+}$.

# CHEMISTRY

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## Key messages

- Candidates should be reminded to read all the information given in a question to ensure they produce full, correct answers.

- Candidates should be encouraged to record burette readings to the nearest 0.05 $cm^3$, even when a titration is not being carried out, as this indicates the level of precision of the apparatus.

- Candidates should be reminded to produce graphs with suitable scales and to construct and extrapolate appropriate lines of best fit. Anomalous points must be clearly indicated.

- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the question paper.

## General comments

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This paper proved accessible to most candidates. Almost all candidates completed all questions indicating that candidates had sufficient time to complete the paper.

## Comments on specific questions

### Question 1

**(a)** Almost all candidates recorded the information required but few recorded their burette readings to the nearest 0.05 $cm^3$. More candidates recorded times to the nearest second as instructed. Most candidates selected appropriate volumes of **FA 1** and water to use in Experiments 3–5. Most candidates calculated the rates of reaction correctly although a significant number of errors in rounding these rates were seen. A number of candidates omitted the unit for rate or gave an incorrect unit rather gave the expected unit of $s^{-1}$. The majority of candidates gained at least partial credit for accuracy in this section.

**(b)** Almost all candidates selected linear scales and most labelled their axes. Errors included too little of the $y$-axis being used and the origin not being included. The plotting was generally good but some made a poor choice for the line of best fit. Candidates should be reminded to indicate points they consider anomalous.

**(c)** Only the strongest candidates answered this question well with many giving vague conclusions such as "increasing concentration increases the rate of reaction". Only a straight line plot with positive gradient going through the origin (or very close to it) indicates that the rate of reaction is

directly proportional to the concentration of **FA 1**. Other lines with a positive gradient would indicate proportionality only.

**(d)** Stronger candidates showed construction lines on their graphs and the value of the rate obtained. While some left their answer to **(i)** as the rate, many others showed the correct working and gained credit in this part. The majority of candidates answered **(ii)** well. Many candidates showed little understanding of the procedure they had carried out in **(a)** and only stronger candidates gained credit in **(iii)** and **(iv)**. A common mistake in **(iii)** was to claim the reaction would be faster and so have greater timing errors. Only the strongest candidates wrote that all the iodine produced would be converted to iodide so no blue-black colour would be seen in **(iv)**.

**(e)** This section discriminated between candidates who were aware of the effect of changing the concentrations of reactants and those who were carrying out the procedure given without referring to their previous experiments. As the concentrations of both the peroxodisulfate and thiosulfate ions were halved compared to Experiment 1, the time obtained in **(i)** should have been the same. Many candidates gained at least partial credit here. The only change in **(ii)** compared with **(i)** was to increase the concentration of thiosulfate ions by a factor of 4 so the time should have increased by the same factor. It was not sufficient to state that the volume or number of moles of thiosulfate ions was increased by 4 without stating that the total volume was unchanged. A common incorrect response was to suggest a shorter time would be obtained in **(ii)** as the concentration of thiosulfate ions was greater.

**Question 2**

**(a)** Most candidates scored at least partial credit in **(i)** for the addition of the alkalis to **FA 4** and **FA 5**. However, not all candidates realised the reason for warming with aqueous sodium hydroxide was to test for the presence of the ammonium ion. Some candidates incorrectly reported red litmus turning blue with **FA 5** thus indicating poor technique. Most candidates gained at least partial credit in **(ii)** but identification of $Cr^{3+}$, $Ca^{2+}$ and $Mg^{2+}$ were amongst the incorrect cations given.

**(b)** Most candidates gained partial credit here with many scoring full credit. The most common response was to use aqueous barium chloride or nitrate followed by a suitable acid. The errors seen were in omitting the name of the acid used after adding the aqueous barium salt, using sulfuric acid, using an unsuitable additional reagent, or not seeing the precipitate dissolving in the acid.

**(c)** This question was only answered well by the strongest candidates. Candidates should be reminded that "gas evolved" is a conclusion and not an observation. Some candidates did not go on to test the gas produced in the reaction with magnesium in **(i)**. Only the better responses noted the formation of a brown gas when **FA 7** was added to **FA 8** and so concluded **FA 8** was $NaNO_2$ in **(ii)**. The majority of candidates correctly identified **FA 7** as $H_2SO_4$. Few candidates were able to provide a correct ionic equation in **(iii)** with one common error being the omission of state symbols.

# CHEMISTRY

## Key messages

- Candidates should not use abbreviations that do not have an internationally agreed meaning. Abbreviations are best avoided altogether, unless they are very well established or used in the syllabus documentation e.g. $\Delta H^{\ominus}$, $S_N1$.

- Candidates should be advised to make sure their answers are given clearly and that any corrected answers are legible.

## 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 of the questions. There was no evidence of candidates being short of time.

## Question 1

**(a)**       It should be noted that for a term that can be exothermic or endothermic, such as enthalpy of solution, answers such as "increases" or "decreases" are ambiguous. Enthalpy of solution should be described as becoming more or less endothermic or more or less exothermic down the group.

**(b)(i)**    Many correct answers were seen here. However, some answers included algebraic expressions that made no sense.

**(ii)**     Many correct answers were seen here.

**(iii)**    Many correct answers were seen here.

**(iv)**     Only the strongest candidates realised that the $Ba^{2+}$ and $Ca^{2+}$ ions are spectators and that the two reactions are the same and their $\Delta H^{\ominus}$ values are the same.

**(c)**       This question was challenging for many candidates. The strongest candidates explained that more moles of gas are consumed in reaction 3. Many answers concentrated on the states of the products only.

## Question 2

**(a)(i)**    Although there were some strong answers here, there were many diagrams that did not have a total of sixteen electrons in the valency shells. Candidates should be encouraged to use as much of the space available as possible so that diagrams are clear.

**(ii)**     The most common error here was to think the HNC bond angle is between 105° and 110°. Since there are three regions of electron density around the nitrogen it will be closer to 120°.

**(iii)**    Many candidates correctly referred to the triple bond in cyanic acid.

**(b)(i)**    This was answered well by the majority of candidates.

**(ii)**     There were many unbalanced equations in response to this question.

**(c) (i)** This question was challenging for many candidates. The presence of two $OH^-$ ions in each formula unit of $Ba(OH)_2$ was rarely understood. However, stronger candidates who calculated a number of moles of $OH^-$ in excess, were able to use this to calculate a concentration.

**(ii)** Some candidates incorrectly over-rounded their answers, leading to answers such as 12 or 13. At least one digit should always be included after the decimal point.

**(iii)** Many smooth curves were seen without end-points. End-points at $10.0\,cm^3$ were rare. Some candidates ignored the starting and finishing pH values they had calculated in **b(i)** and **c(ii)**.

**(d) (i)** Many accurate definitions were seen.

**(ii)** AgNCO was a common incorrect answer, but partial credit was still awarded if the answer showed it uncharged.

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**(iv)** This was challenging for all but the strongest candidates. Most candidates who gave $C_7H_5NO$ in **(iii)** deduced correctly that the amine was phenylamine. A significant number of candidates who got **(iii)** incorrect still managed to offer a sensible structure consistent with their molecular formula, and so gained credit here.

## Question 3

**(a) (i)** This was answered well by stronger candidates. The most frequently seen incorrect answers were 1+ and 2+.

**(ii)** "Ligand substitution" was a frequently seen correct answer. Fewer candidates wrote "oxidation".

**(iii)** The diagrams here should have used the conventions specified in the syllabus, using straight line, wedged and dashed bonds to show 3D. The drawing in of a square equatorial plane, or the use of either wedged or dashed bonds but not both, was not sufficient to show 3D.

**(b) (i)** Many answers were ambiguous and did not state clearly that the co-ordination number is the number of bonds formed by the species in the centre of the complex, rather than the number of bonds formed by each ligand molecule.

**(ii)** Many candidates answered very well here and were able to make correct deductions from the information given.

**(c) (i)** Candidates needed to remember that in a $K_{stab}$ expression every substance should be in square brackets to denote concentration. Charges should not appear outside these square brackets. Units should be given as, for example, $mol^{-1}\,dm^3$, and should not be left in a form that requires further simplification, for example, $1/(mol\,dm^{-3})$ or $(mol^{-1}\,dm^3)^4$.

**(ii)** Some candidates did not take note of the instruction to answer in terms of $K_{stab1}$ and $K_{stab2}$.

**(iii)** Most candidates who wrote an expression in **c(ii)** answered correctly.

## Question 4

**(a) (i)** A frequently seen incorrect answer was "cis-trans", but this is impossible in this ring structure.

**(ii)** The question specified molecular formulae. Interpreting the skeletal formulae as molecular formulae was therefore part of the task, and structural formulae should not have been used. Some candidates offered equations with $H_2$ above the arrow. Since $H_2$ is a reactant here this was not

accepted. Candidates were expected to include $H_2$ on the left of the arrow and to balance the equation.

**(b)(i)** This was generally well answered.

**(ii)** Step 3 was answered well by many, but "diazotisation" was a common incorrect answer for step 5. The diazotisation step in this reaction scheme is step 4.

**(iii)** In step 1 $CH_3CHClCH_3$ is needed. This formula was sometimes given as $C_3H_7Cl$, $CH_3CClCH_3$ or $CH_3CH_2ClCH_3$ and these were not credited. The reagents for steps 2, 3 and 4 were usually given correctly although some omitted "concentrated" in step 2. Some candidates wrote correct temperatures but then added contradictory statements such as heat, boil or reflux.

**(c)(i)** Candidates needed to recognise that when benzene is reduced by hydrogen gas in the presence of a nickel catalyst either elevated temperature or elevated pressure is needed.

**(ii)** Very few candidates completed this part structure correctly.

## Question 5

**(a)** Many candidates found this challenging. Answers were often not sufficiently detailed. For example only giving "carbonyl" group for J, K or L. It was necessary to state that J and L are methyl ketones, and that K is an aldehyde. K was sometimes referred to simply as an "amine". However the experimental observations allow the deduction that it is an *aryl* amine.

**(b)(i)** This was generally answered well.

**(ii)** This was generally answered well.

**(c)** Many candidates found this question challenging. However many candidates did not use the information that J, K, L and M all have the molecular formula $C_9H_{11}NO$ and all contain a benzene ring.

**(d)** While there were many correct answers, a small number of candidates incorrectly gave "benzoic acid".

## Question 6

**(a)** Only the strongest candidates gave a considered, detailed sequence of activities. These started with producing two solutions A and B at $40\ ^\circ C$ before mixing, and involving titration with $HCl$ only after the reaction mixture (or a sample of it) had been quenched with cold solvent.

**(b)(i)** More candidates clearly identified the data they were using and explained how it supported their stated orders.

**(ii)** Most candidates gave a rate equation consistent with their answers in **(i)**, but some had difficulty with the units of *k*.

**(iii)** Candidates who had a correct rate equation usually answered correctly.

**(c)(i)** Many good answers were seen, however errors were frequently seen in the following areas:
- Not showing the dipole on the $C-Cl$ bond;
- Careless drawing of the curly arrow as the $C-Cl$ bond breaks which should start on or near the bond, not on or near one of the atoms;
- Careless drawing of the curly arrow from the $OH^-$ ion which should start on or near a lone pair, not on or near one of the atoms or the minus charge;
- Omitting the electric charge on the intermediate or transition state.

**(ii)** "Two optical isomers will form because there is a chiral carbon atom" was frequently seen as an answer. However this does not take into account the single optical isomer used as the reactant. Because of this the product will be a single optical isomer if the mechanism is $S_N2$, because the $OH^-$ can only attack the $C^{\delta+}$ from one side. The product will be a mixture of two optical isomers if

the mechanism is $S_N1$, because the $OH^-$ can attack the $C^+$ of the planar intermediate from either side.

**(d)**    This was generally answered well, although some candidates did not make use of the formula given in the question and instead based their answers around groups from the *Data Booklet*. This approach did not work.

Some candidates wrote e.g. "CHOH" in the "group responsible" column. This received no credit as it was not clear whether the CH proton or the OH proton is being referred to.

Some candidates did not use the correct words to describe the splitting patterns: *singlet*, *doublet* and *quartet* (or *quadruplet*). The splitting of the CH peak (by the $CH_3$ protons) was often incorrectly described as a multiplet.

# CHEMISTRY

| Paper 9701/42 |
| **A Level Structured Questions** |

## Key messages

- Candidates need to show clear working in mathematical questions as where a final answer is incorrect often credit can be obtained for correct working.

- Candidates should ensure they read the questions carefully so that they answer the question as it has been set.

## 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 of the questions. There was no evidence of candidates being short of time.

## Comments on specific questions

### Question 1

**(a) (i)**   Many candidates gained credit here and gave the correct trend for the ionic radii of cations. However some stated the polarising power of the cation decreases and did not state what is being polarised, i.e. the carbonate ion, $CO_3^{2-}$.

**(ii)**   Many candidates knew that $Na^+$ has a larger radius or smaller ionic charge but did not fully explain their answer.

**(b) (i)**   A number of correct answers were seen. Some candidates gave an incorrect equation with $K_2O$ or $KCO_3$ as a product.

**(ii)**   This question was well answered.

**(c) (i)**   Some excellent answers were seen for this question. However common errors included missing out multiples, missing out the divisor, using 150 for the bond energy of oxygen instead of 496, or omitting 496.

**(ii)**   This was challenging for many candidates. A number of candidates did not refer to the stronger attraction between the ions.

### Question 2

**(a)**   This was generally well known but a number of candidates did not identify the correct colours of the precipitates.

**(b) (i)**   Most candidates answered well here.

**(ii)**   Stronger candidates gave a coherent and well-structured procedure. However, this proved challenging for many candidates who did not understand how to get the required data and there was some confusion between measuring conductivity with voltage or current. In addition, many did not mention volumes or state that the temperature should be kept at 40 °C.

**(c)(i)**    Most candidates recognised the reaction was first order for both reactants. However some did not clearly explain their evidence by linking to the experimental data.

**(ii)**    Many candidates correctly stated the rate equation and the units of the rate constant, $k$.

**(iii)**    This was well answered.

**(d)(i)**    Most candidates correctly showed the $\delta+/\delta-$ dipoles on the C-C$l$ group, but often curly arrows were not clearly drawn or the lone pair on the iodide ion, $I^-$, was absent. Some only showed a single step in their mechanism and omitted the intermediate ($S_N1$) or the transition state ($S_N2$).

**(ii)**    This question was challenging for most candidates and many did not show understanding of the relationship between the mechanism and formation of stereoisomers.

**(e)(i)**    This was well answered.

**(ii)**    Many candidates gained partial credit here. Common errors were 1-chlorobutane or redrawing 2-chlorobutane.

## Question 3

**(a)**    This was well answered although many omitted the lone pair on the sulfur or did not use all the information given and drew a trivalent sulfur atom.

**(b)(i)**    The first equation was normally correct, although fewer gained full credit producing $NaHSO_4$ or $Na_2SO_4 + H_2$ as the products in the second equation.

**(ii)**    Many candidates found this challenging.

**(iii)**    A number of correct answers were seen but some did not link their equations in **(b)(i)** to **(b)(ii)**.

**(iv)**    Many candidates answered this correctly giving the reciprocal of their answer to **(b)(iii)**.

**(v)**    Many candidates found this challenging and did not give a molecular formula or viable R group.

**(c)(i)**    This was generally well known.

**(ii)**    While stronger candidates answered correctly, many other candidates did not follow the instruction and gave structures of angelic acid and **T** with no stereoisomerism. Structure **U** was usually correct.

**(iii)**    This question was marked based on the structures given in **(c)(ii).** This was generally well answered by candidates.

## Question 4

**(a)(i)**    Most candidates gave the correct answer here.

**(ii)**    There were some good answers here but many candidates found it difficult to process the information given in the question. The table was often left blank.

**(b)(i)**    This was well known.

**(ii)**    Many candidates gave two correct square planar structures. The quality of the diagrams was generally good.

**(iii)**    Most candidates answered this question well.

## Question 5

**(a)(i)**    This was answered well with candidates showing good knowledge of the definitions of bidentate and ligand.

**(ii)** Many good answers were seen here. A common error was to give two isomers with the same three-dimensional structure and a few candidates gave three trans structures.

**(b)(i)** This was answered well by many candidates. Some candidates made careless errors, such as ionic charges outside the final square brackets.

**(ii)** This was answered well by many candidates. A common error was inverting the ratio.

**(iii)** Many fully correct answers were seen.

**(c)(i)** Most candidates found this challenging and struggled with the concept of entropy change. Many did not use the information in the question.

**(ii)** Many candidates gave the correct answer to this question. Common incorrect responses included using incorrect equations or not dividing $\Delta S$ by 1000.

**(iii)** This was generally well answered.

**(iv)** Only the strongest candidates selected the relevant information from the table to calculate the $\Delta H$.

**(v)** This was well known.

## Question 6

**(a)(i)** This question was usually correctly answered. A common error was comparing $pK_a$ to the relative acidity.

**(ii)** Most candidates gave the correct answer here.

**(iii)** This was usually well known but some candidates did not specify that the O-H bond would weaken or the conjugate base would be stabilised.

**(b)(i)** Most candidates found this challenging and did not start with the zwitterionic structure of the amino acid. A common error was deprotonating a glycine molecule.

**(ii)** Many fully correct answers were seen for this question.

**(iii)** This was answered well by many candidates. Common errors were a lack of a vertical section at $10.0 \text{ cm}^3$ and incorrect starting and ending pH values.

## Question 7

**(a)** Some excellent answers were seen that identified all or most of the functional groups. However, many incorrect answers were seen; candidates did not relate the test results to the functional group.

**(b)** Most candidates gained at least partial credit here. This analysis proved difficult for many candidates and some did not draw structures with the molecular formula $C_8H_7ClO$. The identification of a chiral centre in one of their products was better known.

## Question 8

**(a)(i)** This was answered well by many candidates.

**(ii)** Many candidates answered this correctly.

**(iii)** This was only answered well by stronger candidates. The most common errors were to:
- omit $AlCl_3$ or use $ClCH_2CH_2CHO$ in step 1;
- use KCN or HCN alone in step 2;
- omit aqueous or heat in step 3;
- omit heating under pressure in step 5.

**(iv)**    This was answered well by many candidates. Common incorrect answers included:
- Omission of the sodium salt for the phenol and/or carboxylic acid with an of excess NaOH(aq);
- Substitution of a ring hydrogen or the $NH_2$ group with $Cl$ with an excess of $HCl$(aq);
- Formation of the 3,5-dibromophenol derivative with an excess of $Br_2$(aq).

**(b)(i)**    Many candidates correctly identified spot **P** as tyrosine. However most candidates did not fully explain their answer usually stating it was due to its 2– charge.

**(ii)**    Only the strongest candidates answered this question correctly.

# CHEMISTRY

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**(ii)** "Two optical isomers will form because there is a chiral carbon atom" was frequently seen as an answer. However this does not take into account the single optical isomer used as the reactant. Because of this the product will be a single optical isomer if the mechanism is $S_N2$, because the $OH^-$ can only attack the $C^{\delta+}$ from one side. The product will be a mixture of two optical isomers if

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# CHEMISTRY

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Paper 9701/51
Planning, Analysis and Evaluation
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## General comments

The understanding of significance of figures is important in science and it is necessary to consider data in relation to that.

Candidates should be encouraged to read through their answers before submitting their papers. For example **Question 2(c)(i)** asks for 15.00 cm$^3$ of a two component solution yet many candidates gave, for example, volume combinations of 32.145 and 17.142, 2.14 and 0.525 which did not total 15.00.

Candidates should be discouraged from providing multiple responses to a simple question, as this often leads to a contradiction within the answer. For example in **2(c)(ii)** candidates often presented a list answer with two pieces of apparatus from burette, pipette or measuring cylinder which would gain no credit.

Candidates should be given more practice in answering evaluative type questions such as those required to answer **1(i)** and **2(d)**.

Calculations should be presented in a logical way with any mistakes clearly crossed out.

As preparation for this paper, candidates would benefit from performing or observing more chemistry practical work.

## Comments on specific questions

### Question 1

(a) This question required the candidates to determine the enthalpy change when anhydrous calcium chloride dissolves in water. A number of candidates presumed a more complex situation of using a heat bag which complicated their diagrams unnecessarily. All that was required was anhydrous calcium chloride and water. Further the last part of the question was to consider the graph of results to see the variables producing the graph and thereby including labelled equipment that would measure these variables. As with all calorimetry experiments, insulation is required and its omission was the most common error. Also, to be effective, the thermometer had to be in the solution.

(b) A standard procedure with calorimetry experiments is to start only when the apparatus is in stasis with its surroundings, the first six readings of temperature (21.5 °C) were to ensure that this was the case. Whilst this also determines the initial/room temperature that is not the purpose of a series of readings taken to ensure a steady temperature.

(c) The reading at 3.5 minutes was much increased at 36.5 °C and this should have prompted the candidates to realise that the dissolution had started. The anhydrous calcium chloride had been added and the temperature was rising rapidly, making it not feasible to take a temperature reading. Some candidates stated that this was the point where water was added to the experiment, that it was stirred or the temperature had not changed.

(d) The data plotted on the graph clearly shows the temperature increasing in the 3.5 to 4.5 minute section. A number of candidates offered that this was due to an exothermic reaction or energy being released rather than that the anhydrous calcium chloride was still dissolving. Responses involving energy or temperature were essentially a re-statement of the question. Some candidates supposed anhydrous calcium chloride was added at this point or that it had just started dissolving.

**(e)**     Only a few candidates were successful in this question. This was an exothermic reaction with a cooling curve after the end of the reaction where the temperature/time plot is used to deduce the temperature change. This is a standard procedure that should have been well known to candidates.

Very few candidates completed the straight line from 0 to 2.5 minutes and extrapolated to 3 minutes. Some candidates attempted to draw a straight line on the cooling part of the plot, but most of those connected the points at 6, 7 and 8 minutes which is lower than the line of best fit. Most, but not all, of these lines were extrapolated to 3 minutes. As well as the two lines required by the question there was a large number of other lines. A few candidates drew a curve from 3.5 to 10 minutes. A popular line was a straight line from 3.5 to 4.5 minutes (sometimes extrapolated to 3 minutes), There were many diagonal straight lines from 0 or 2.5 minutes up to 3.5 minutes or other points and other lines at the top of the plot, even including the anomalous point. None of these lines were pertinent to the experiment.

The second part of the question required the determination of temperature from the two lines. Given the array of lines a value where one such line crossed the 3 minute line was accepted as the upper value for the purpose of calculation with the lower value of 21.5. Many candidates only gave the upper value even though the question clearly asks for the temperature rise (from the start value). Finally, at the end was a requirement for a result given to one decimal place which was, unfortunately, was not always followed.

**(f)**     The anomalous result was clearly at 8.5 minutes (temperature reading too low) but some had others, often 3.5, which showed the data was not understood. Many candidates gave the temperature outside the experiment was lower, without carrying on to what happened when the thermometer was replaced in the experiment as stated in the question. This replacement being just before 8.5 minutes meaning there was not enough time for the thermometer to respond to the experiment's temperature so showed a lower temperature. Too many candidates did not seem to realise that the thermometer was returned to the solution. A small number of candidates took replace to mean using a different thermometer. This was accepted provided the response of the new thermometer was the same as the original.

**(g)**     There were a number of acceptable responses such as uniformity of heating or ensuring complete dissolving. The majority of candidates scored well here with most responses in uniformity of heating.

**(h)**     Again, virtually all candidates scored well here. The obvious response of gloves to prevent skin irritation was the most acceptable answer. It was unnecessary to qualify gloves but many candidates did. Unfortunately some related the gloves to protection from heat.

**(i)**     The simplest calculation method involved how much energy would give a 30 °C temperature rise in 75 g water (9405 J) then calculating moles from that value and the given 82 500 J (0.114), then using that value and the $M_r$ of calcium chloride (111.1) to 12.7g. Most successful candidates followed this line. Some errors were made by some, perhaps thinking that 30 °C was an absolute temperature rather than a difference and used 303 instead of 30. A number had 75 + x as the mass of surroundings where x was the mass of calcium chloride. A few made an error in the calculation of $M_r$ and others in the conversion of J to kJ or vice versa.

## Question 2

**(a) (i)**     The plotting of the data was generally well done. The introduction to the question gave the relationship between the angle of rotation and the solution concentration, $\alpha_{obs} = [\alpha]c$ which is of the form y = mx. Thus the line had to go through the origin. There was ± half square tolerance at either end of the line. The majority of candidates did not produce a good line. Most errors were in terminating the line before the origin or missing the origin.

**(ii)**     Only a few candidates did not identify the most anomalous point

**(iii)**     The provision of two co-ordinates was better done than in previous years. Though some candidates gave just one x and one y value, or gave the two x values then the two y values, or the x and y values inverted. Also of significance was the range over which is best for the gradient calculation. In this particular graph a minimum of 0.03 on the x axis was required. The calculation

of the gradient from the candidates' data was usually well done. Only a few candidates calculated the inverse value. Unfortunately, many candidates who calculated a correct value did not quote it to two decimal places as required by the question. Others truncated numbers such as 67.6855 to 67.68 instead of 67.69.

**(b)(i)** It was surprising that so many candidates did not carry out the simple calculation required for this question ($0.075 \times 250 = 18.75$).

**(ii)** The essential elements in preparing a standard solution should be well known. The essentials are dissolving a known mass of sucrose in distilled water in a beaker, then transferring all of that solution into a volumetric flask and making it up to the mark with distilled water. Some candidates went into great detail about the weighing of the solute but omitted details about producing a solution. There were some unusual methods of solution transfer to the volumetric flask including pipette or burettes – none of which were necessary. The taking of an aliquot of the solution in the beaker to the volumetric flask is incorrect. It was essential to use distilled water in making the solution.

**(c)(i)** This question required a ratio of ($0.035/0.075$) applied to $15.00\,\text{cm}^3$ giving $7.00\,\text{cm}^3$ of sucrose solution, then $8.00\,\text{cm}^3$ water. Most incorrect responses seemed to ignore the requirement of $15\,\text{cm}^3$ solution since the total volume of the two solutions was not $15\,\text{cm}^3$.

**(ii)** Too many candidates proposed the use of measuring cylinders in such a situation which requires a more precise volume measurement. Also pipettes of 7 or $8\,\text{cm}^3$ are not available so just having a pipette would not suffice. Graduated pipettes would suffice but only for volumes up to $25\,\text{cm}^3$ in order to retain precision. A burette was the best response in this situation.

**(iii)** Many candidates realised that the reason for the lower value of rotation was the solution was more dilute than expected but did not state that. It was necessary to state that more water or less sucrose solution than expected was used. A number of candidates stated less sucrose was used but did not specify that it was a sucrose solution. Some responded that the sucrose solution had been made with too little sucrose indicating that the details of the procedure had not been understood. Others erroneously presumed that the solution tested was too concentrated or that merely the student read an angle wrongly which was an irrelevant response.

**(d)** This was a multiple calculation where the first stage was to deduce a concentration in $g\,\text{cm}^3$ then to process that value into a $mol\,\text{dm}^{-3}$ concentration by way of $M_r$ and a 1000 factor. Quite a number of candidates proceeded no further than the first marking point perhaps wrongly assuming that this was a concentration in $mol\,\text{dm}^{-3}$

**(e)** The best way of preparing the cell is to rinse it out (a few times) with the solution that is about to be tested. Alternately rinsing with distilled water was fine but in this case it must also be dried. Responses that did not include using distilled water or drying or both were common.

**(f)** The introduction of the question clearly states that optical rotation depends on the solution concentration. Also in the introduction, the expression $\alpha_{obs} = [\alpha]c$ is defined in the context of a cell of 10 cm. Given that cell length, and the doubling of the cell length in the question, some candidates were able to consider that cell length was a factor in optical rotation. The predicted value of double could be worked out from $2 \times 5.05$, or $2 \times$ graph value with an explanation based on light encounters twice as many molecules.

**(g)** Most candidates had good responses to this question based on the use of water as a reference point.

# CHEMISTRY

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

## Key messages

Candidates should be discouraged from providing multiple responses to a simple question, as this often leads to a contradiction within the answer. For example, **1(d)** required the independent variable and the dependent variable: only one response should be provided to each of these sub-questions. This was also the case in **2(e)(ii)** where the name of one piece of apparatus was required.

Candidates' answers should relate directly to the procedures and problems relevant to the experiment described in a question. This applied particularly to the practical based problems seen in **Question 1**.

## General comments

Candidates answered the questions on this paper more successfully than in recent years with strong responses seen to many theoretical and numerical parts. Some responses to questions involving practical applications were often less well answered.

As preparation for this paper, candidates would benefit from performing or observing more chemistry practical work.

Candidates should be aware of the need for the appropriate number of significant figures and correct rounding.

## Comments on specific questions

### Question 1

**(a)**     Only a few candidates were awarded full credit for this question. Four hazards associated with lead and its oxides were given. It was expected that candidates would select two hazards and would give one precaution for each hazard. Many candidates suggested hazards of lead and its oxides that do not exist. Candidates were expected to apply the information to laboratory scenarios: e.g. 'may cause long term damage to the aquatic environment' should elicit the precaution 'do not dispose of down sinks/drains'.

**(b)**     Some candidates found the calculations for the third column of the table the most challenging.

**(c)(i)(ii)** It was expected that candidates would convert the ratios of oxides, **A**, **B** and **C** from 14 : 7 : 10.5, to 2 : 1 : 1.5 and then realise that these numbers could be double to give a simple whole number ratio of 4 : 2 : 3, and thus would support Dalton's Law.

**(d)**     Many candidates were unsure of the independent variable and the dependent variable.

**(e)(i)(ii)** Most candidates gained credit for determining the empirical formula of oxide **B** and knew how to convert an empirical formula into a molecular formula.

**(f)**     Some candidates realised the possibility of re-oxidation, though others suggested that the flow of methane gas would be needed to sweep away any oxygen released by the oxides of lead. A significant minority suggested the resultant lead would weigh more at higher temperatures as a consequence of it becoming expanded.

**(g)**     A significant proportion of candidates were unaware that heating to constant mass is a simple method of checking that a reaction may be complete.

**Question 2**

**(a) (i)**     Most candidates did not realise that the purpose of taking an initial reading without any solute present was for calibration. However many sensible responses based upon the idea of a need for a control, such as 'to provide a reference reading' were allowed.

**(ii)**     Most candidates were aware of the reasons to clean substances from the outside of the cuvette.

**(b) (i)**     This calculation was answered correctly by the vast majority of the candidates.

**(ii)**     Candidates are becoming more familiar in how to make up a standard solution but many candidates stated that the solid solute should be added directly into the volumetric flask rather than dissolving in distilled water followed by simple transfer of the solution into the volumetric flask prior to topping up the volumetric flask with distilled water.

**(iii)**     There were many good responses here. Some candidates realised that 0.0474 g could not be measured on a two decimal place balance. Others suggested that the percentage error in the mass reading would become significant.

**(c)**     The vast majority of candidates showed they could read from graphs correctly.

**(d) (i)**     As already pointed out, graphical work continues to improve and the majority of candidates gained full credit here. If an anomalous point appears in a graph candidates should be advised to check their plotting.

**(ii)**     Usually the relationship between concentration and absorbance was correctly stated but a significant number of candidates did not explain this relationship with reference to particles.

**(iii)**     Most candidates related reliability to the number of plots on or close to the line of the graph.

**(e) (i)**     Most candidates found this calculation difficult. Some candidates did not produce a combined volume of 25.00 cm$^3$.

**(ii)**     Having been told the volumes required in **2(e)(i)** should be to two decimal places, it was expected that even if the calculation was incorrect, the answer to **2(e)(ii)** would be a burette.

**(f) (i)(ii)**     The majority of candidates correctly read the value from their graph for part **(i)** and were able to use it in the calculation in part **(ii)**.

**(g)**     Most candidates were able to calculate a correct answer. For some their answer to **2(f)(ii)** resulted in a percentage of manganese content of over 100%. This was the reason why an alternative value for the mass of manganese present in the steel was given in the question. It was expected candidates should have realised that an impurity value of above 100% was an impossible value. A significant number of candidates showed a poor appreciation of rounding. For example, where rounding was done twice such as 0.11497 rounded to 0.115 in the working and then given as 0.12 on the answer line.

**(h)**     The majority of candidates gained credit here for appreciating the potential to oxidise the $Fe^{2+}$ ions.

# CHEMISTRY

## General comments

The understanding of significance of figures is important in science and it is necessary to consider data in relation to that.

Candidates should be encouraged to read through their answers before submitting their papers. For example **Question 2(c)(i)** asks for 15.00 cm$^3$ of a two component solution yet many candidates gave, for example, volume combinations of 32.145 and17.142, 2.14 and 0.525 which did not total 15.00.

Candidates should be discouraged from providing multiple responses to a simple question, as this often leads to a contradiction within the answer. For example in **2(c)(ii)** candidates often presented a list answer with two pieces of apparatus from burette, pipette or measuring cylinder which would gain no credit.

Candidates should be given more practice in answering evaluative type questions such as those required to answer **1(i)** and **2(d)**.

Calculations should be presented in a logical way with any mistakes clearly crossed out.

As preparation for this paper, candidates would benefit from performing or observing more chemistry practical work.

## Comments on specific questions

### Question 1

**(a)**     This question required the candidates to determine the enthalpy change when anhydrous calcium chloride dissolves in water. A number of candidates presumed a more complex situation of using a heat bag which complicated their diagrams unnecessarily. All that was required was anhydrous calcium chloride and water. Further the last part of the question was to consider the graph of results to see the variables producing the graph and thereby including labelled equipment that would measure these variables. As with all calorimetry experiments, insulation is required and its omission was the most common error. Also, to be effective, the thermometer had to be in the solution.

**(b)**     A standard procedure with calorimetry experiments is to start only when the apparatus is in stasis with its surroundings, the first six readings of temperature (21.5 °C) were to ensure that this was the case. Whilst this also determines the initial/room temperature that is not the purpose of a series of readings taken to ensure a steady temperature.

**(c)**     The reading at 3.5 minutes was much increased at 36.5 °C and this should have prompted the candidates to realise that the dissolution had started. The anhydrous calcium chloride had been added and the temperature was rising rapidly, making it not feasible to take a temperature reading. Some candidates stated that this was the point where water was added to the experiment, that it was stirred or the temperature had not changed.

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