

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

This examination paper provided a suitable challenge to the candidates. The statistics for individual questions suggest that the majority of candidates were able to finish the paper within the hour allowed.

Eleven questions can be said to have been found to be more accessible; **Questions 4, 5, 8, 13, 15, 16, 20, 21, 26, 29 and 34**. Six questions can be said to have been found to be more challenging; **Questions 3, 6, 9, 10, 18 and 36**.

Comments on specific questions

Question 3

The most commonly chosen incorrect answer was **A**. The fuel that produces the largest mass of CO₂ is the one that has the highest percentage of carbon. Biodiesel is 76% carbon, octane is 84% carbon, so the answer is **C**.

Question 6

The most commonly chosen incorrect answer was **B**. Option **A**, iodine, has both covalent bonds within the molecules and intermolecular forces between the molecules, so this is the answer. Option **B** is SiO₂, in which all the bonds are covalent. Option **C** is sodium chloride, in which all the bonds are ionic. Option **D** is zinc, in which all the bonds are metallic.

Question 9

The correct answer, **B**, was chosen by only 21% of candidates. The oxidation number of nitrogen in hydroxylammonium ions is -1 . If two Fe³⁺ ions are reduced to two Fe²⁺ ions they are gaining one electron each, this is a total of two electrons. While this reduction is happening one hydroxylammonium ion is oxidised in the same reaction, its oxidation number must therefore increase by two. Since $-1 + 2 = +1$ the final oxidation number of nitrogen must be $+1$. The answer is therefore N₂O.

Question 10

In this question, the candidate can eliminate option **C** straight away as it has a pair of elements in which element X has a lower first ionisation energy than element Y, thus not agreeing with the statement in the question.

The candidate then needs to decide for which pair of elements only one of the students is correct.

The most commonly chosen incorrect answer was **A** but in option **A** both students are correct. Option **B** has neither student correct. Option **D** has only student 2 correct and so is the correct answer.

Question 18

The most commonly chosen incorrect answers were **B** and **C**. Since 1.53 g of gas is produced, this means that 1.47 g of metal oxide is produced. This means that the answer is a group 2 metal for which:

$$(M_r \text{ of oxide} / M_r \text{ of nitrate}) = 1.47/3.00 = 0.49.$$

This is true when $M = \text{Sr}$, so the answer is **D**.

Question 36

The most commonly chosen incorrect answer was **B**. The majority of candidates therefore knew that statements 1 and 2 were correct, but only a minority knew that statement 3 was correct.

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Paper 9701/12
Multiple Choice

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

General comments

This examination paper provided a suitable but quite accessible challenge to the candidates. The statistics for individual questions suggest that most candidates were able to finish the paper within the hour allowed.

Fifteen questions can be said to have been found to be more accessible; **Questions 1, 8, 9, 10, 13, 16, 17, 18, 22, 25, 26, 29, 31, 32** and **34**. Six questions can be said to have been found to be more challenging; **Questions 11, 24, 28, 30, 35** and **38**.

Comments on specific questions

Question 11

The most commonly chosen incorrect answer was **D**. When a catalyst was used the activation energy was lower, therefore under the new conditions the activation energy has increased so the answer is **B**. Since the rate has not changed, the number of successful collisions per unit time has not changed, so choices **C** and **D** are incorrect.

Question 24

The most commonly chosen incorrect answer was **B**. Options **A** and **D** do not have optical isomers, so these are both incorrect. Option **B** is 2-chloropentane that does have optical isomers. However when it is treated with sodium hydroxide in ethanol it gives three alkenes, pent-1-ene, *cis*-pent-2-ene and *trans*-pent-2-ene. Option **C** is 2-chloro-3-methylbutane that does have optical isomers. When it is treated with sodium hydroxide in ethanol it gives two alkenes, 3-methylbut-1-ene and 3-methylbut-2-ene, so this is the correct answer.

Question 28

The most commonly chosen incorrect answer was **C**. From the reaction scheme it can be deduced that P is $\text{CH}_3\text{CH}(\text{OH})\text{CN}$ and that Q is $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$. R is a diester as stated in the question, its molecular formula is $\text{C}_6\text{H}_8\text{O}_4$ and its empirical formula is $\text{C}_3\text{H}_4\text{O}_2$, hence the answer **B**.

Question 30

The most commonly chosen incorrect answers were **A** and **D**. The lack of a broad absorption between 2500 and 3000 cm^{-1} rules out **A**. The lack of a broad absorption between 3200 and 3600 cm^{-1} rules out **B** and **D**.

Question 35

The most commonly chosen incorrect answer was **B**. The question requires careful solving including the production of balanced chemical equations.

In 1, 0.710 g of chlorine is 0.01 moles, this produces 0.02 moles of hydrogen chloride and this has a mass of 0.730 g, so statement 1 is true.

In 2, 0.01 moles of chlorine produces 0.01 moles of sodium chloride and this has a mass of 0.585 g, so statement 2 is true.

In 3, 0.01 moles of chlorine produces $0.01 \cdot \frac{5}{3}$ moles of sodium chloride and this has a mass of 0.975 g, so statement 3 is true and the correct answer is **A**.

Question 38

The most commonly chosen incorrect answer was **C**. An alcohol that gives a positive iodoform test must have a $-\text{CH}(\text{OH})\text{CH}_3$ group.

Ethanol does but ethane-1,2-diol doesn't, so pair 1 can be distinguished.

Propan-2-ol does but methylpropan-2-ol doesn't, so pair 2 can be distinguished.

Ethanol does and butan-2-ol does, so pair 3 cannot be distinguished and the correct answer is **B**.

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Paper 9701/13
Multiple Choice

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

General comments

This examination paper provided a suitable and accessible challenge to the candidates. The statistics for individual questions suggest that most candidates were able to finish the paper within the hour allowed.

Ten questions can be said to have been found to be more accessible; **Questions 1, 2, 3, 7, 8, 9, 10, 15, 29, and 34**. Six questions can be said to have been found to be more challenging; **Questions 19, 22, 26, 32, 37 and 38**.

Comments on specific questions

Question 19

Options **A**, **C** and **D** were equally popular incorrect answers. The reaction between an ammonium salt and a base produces ammonia, which is therefore **W**. When ammonia reacts with chlorine it gives an element **X** and an acidic gas **Y**. **X** must be nitrogen and **Y** must be hydrogen chloride. **Y** reacts with ammonia to give **Z**. **Z** is therefore ammonium chloride, hence the answer is **B**.

Question 22

Options **A**, **B** and **C** were equally popular incorrect answers. Since the monomer for PVC is chloroethene the repeat unit of PVC is $\{-\text{CH}_2\text{CHCl}-\}$. Statement **D** is the only incorrect statement, so **D** is the correct answer.

Question 26

The most commonly chosen incorrect answer was **C**. 0.0075 moles of **X** burn to give 0.0300 moles of CO_2 , so each molecule of **X** has four carbon atoms, leaving **A** and **B** as possible answers. **B** cannot be oxidised by acidified potassium dichromate(VI), so the correct answer is **A**.

Question 32

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

- 1 This statement is correct as the Group 2 carbonates get more stable down the group.
- 2 This statement is correct as the Group 2 hydroxides get more soluble down the group.
- 3 This statement is correct as the Group 2 elements lose electrons more easily down the group.

Hence the correct answer is **A**.

Question 37

The most commonly chosen incorrect answer was **D**.

Compound 1 will be reduced to pentan-2-ol which has a chiral carbon atom.

Compound 2 will be reduced to 3-hydroxypent-1-ene, which has a chiral carbon atom.

Compound 3 will be reduced to pentan-3-ol which doesn't have a chiral carbon atom, hence the correct answer is **B**.

Question 38

The most commonly chosen incorrect answer was **B**. The only possible formula for **Y** is $\text{C}_4\text{H}_9\text{Br}$, therefore **Y** is 2-bromobutane.

- 1 This is true.
- 2 This is true, the alkenes are but-1-ene and but-2-ene.
- 3 This is true, the alkenes are *cis*-but-2-ene and *trans*-but-2-ene.

Hence the correct answer is **A**.

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Paper 9701/21
AS Level Structured Questions

Key messages

Candidates are reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required: the accurate use of chemical terminology is welcomed, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument.

Candidates are reminded to address 'explain' questions fully – not merely to state facts, but then to show how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules, in particular organic species.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Early rounding of numbers should be avoided.

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. recall questions were answered very well on the whole; candidates are reminded to write succinctly as lengthier answers often lead to unfortunate contradictions.

Where numerical answers were required in this paper the best answers involved clearly laid out working. Candidates are also asked to ensure their drawings are clear and unambiguous.

Scripts were generally clear and well presented; as a general point of presentation, it is difficult for examiners to read scripts where answers written in pencil have been overlaid with ink without rubbing out the pencil.

Comments on specific questions

Question 1

- (a) (i) There were many good, detailed answers, though a significant minority did not state that catalysts increase the rate of reaction.
- (ii) There were many good answers to this question. Some candidates confused homogeneous and heterogeneous, or heterolysis and heterogeneous.
- (b) This was answered well by many; though common errors were to ignore the stoichiometry of the reaction, or to miscount the number of S=O bonds in SO₂ and SO₃ (four and six respectively).
- (c) Many candidates did not recognise that the third point required the activation energy for the decomposition reaction, hence D not C.
- (d) (i) Candidates were required to refer to collision theory in order to gain full credit here. The best phrase to employ in such instances is the 'increase in the frequency of successful collisions', as other attempts, (e.g. 'more frequent successful collisions') can be ambiguous. Many candidates answered in terms of equilibrium yield, which gained no credit.
- (ii) This question was generally answered better than (d)(i), though often candidates repeated their words from the previous part.

- (e) This question was answered well. Some candidates gave the reverse equation, to no credit.
- (f) (i) Many candidates did not appreciate the ability of sulfur to expand its octet and accommodate ten electrons in its outer shell, having formed two double bonds with oxygen. Other incorrect answers gave sulfur two lone pairs.
- (ii) There were many good answers to this question.
- (iii) A surprising number of candidates were unable correctly to show the reaction of H_2SO_4 and H_2O and give the correct state symbols.

Question 2

- (a) Credit was available for statements linking the varying number of electrons, and the varying strength of dispersion forces. Many candidates gained credit, but there were also many incorrect references to hydrogen bonding.
- (b) Most answers to this question were correct, but many candidates did not receive credit as they wrote about *how* molecules are cracked rather than *why*.
- (c) (i) This item was answered well. Some candidates did not include $2\text{C}_2\text{H}_4$ or gave C_2H_6 as the formula for ethene.
- (ii) This item was answered well.
- (iii) The vast majority of candidates gained at least partial credit here. Candidates are reminded that there is no link between the disposal of pure hydrocarbons and the chemical attack of the ozone layer.
- (iv) Many candidates answered this well, but there were two skills required here: the first the identification of the correct monomer; the second the showing of all bonds, as required by a displayed formula.

Question 3

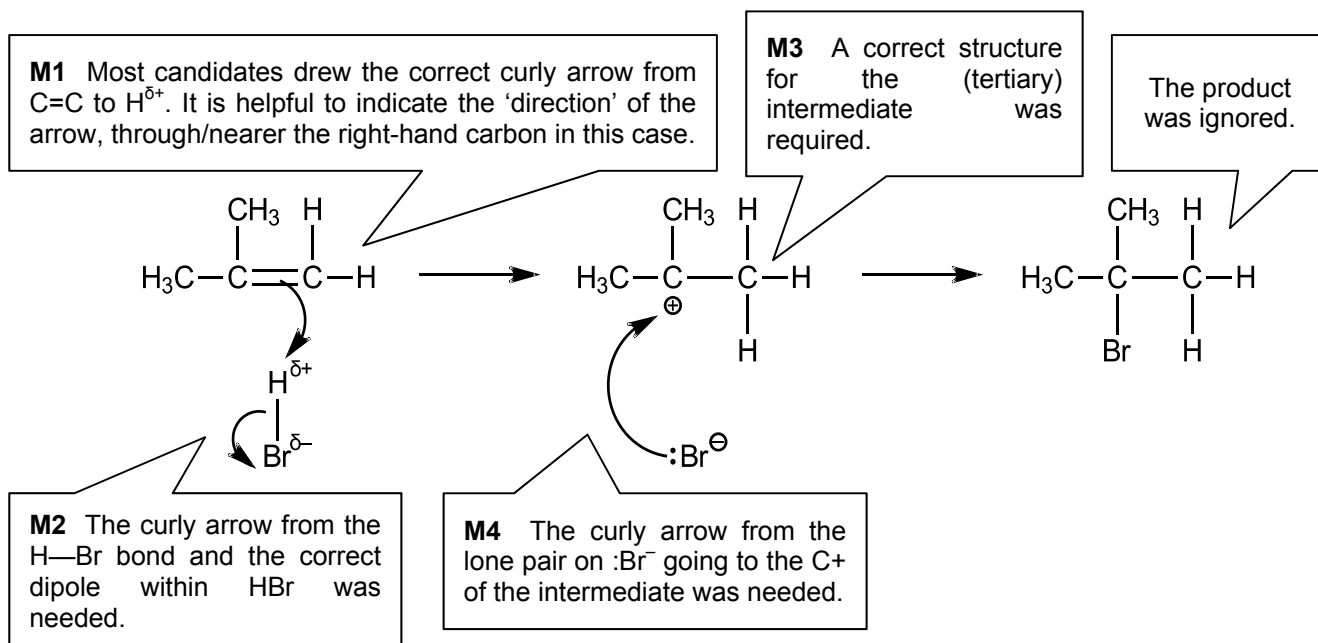
Whilst candidates were able to show that they understood the questions, answers required more precision and different concepts were often confused. Candidates are advised not simply to answer every question with generic information, as contradictions often arise this way.

- (a) (i) This was answered well, though candidates should beware any suggestion that the distance of electrons in the outer shell remains the same across the period: this is clearly wrong if atomic radii decrease with increasing proton number.
- (ii) Answers needed to stipulate that electrons are lost from the outer shell, or that the outer shell itself is lost during ionisation.
- (iii) It was sufficient for candidates to state that electrons are gained, but many answers required more detail that increased repulsion/shielding of the nucleus came from the outer shell.
- (b) (i) Examiners were looking for careful use of terminology here: candidates must not use shell/sub-shell/orbital interchangeably.
- (ii) Many candidates were able succinctly to highlight the paired electrons in a 3p orbital and the resulting repulsion.
- (c) (i) Candidates are reminded to include even the most basic information in their answers: for items with several marks, examiners are looking for complete description of the trends.
- (ii) Many candidates answered this well, though a particularly common error was to form NaOH and HCl from NaCl and H_2O .
- (iii) This question was answered well by many candidates.

Question 4

These items required precise language, drawing and spelling for full credit to be awarded. Candidates are reminded of the need for legibility of technical words, particularly systematic names where a letter's difference can give a wrong answer.

- (a) (i) There were many good answers to this item. Triodomethane and iodoform were both acceptable answers, but iodomethane or triiodoform were not.
- (ii) This was answered well by most, but candidates should make sure their syntax is correct: butan-2-ol is the accepted variant, not buta-2-nol, but-2-anol or other attempts.
- (b) **X** is the secondary alcohol butan-2-ol, so the collection of isomers needed not to repeat this structure.
- (c) (i) This item was answered well.
- (ii) Most answers to this question were correct. A common error was to put the wrong charge on the dichromate(VI) ion. Examiners did not credit the alternative answer (*acidified*) *manganate* without an oxidation state for the anion — though both (VI) and (VII) were accepted.
- (iii) Most candidates were able to identify but-1-ene and but-2-ene. Many then incorrectly opted for methypropene as the third isomer.
- (d) (i) This question saw many good answers. Candidates often gave an incorrect intermediate (often the primary carbocation $(\text{CH}_3)_2\text{CHCH}_2^+$ was given), or very loosely sketched curly arrows that did not clearly indicate the origin/destination of electron pairs. Some candidates did not show the induced dipole in HBr, or the lone pair of electrons on the bromide anion.



- (ii) Examiners credited answers that gave a comparison between the relative stabilities of the primary and tertiary carbocation intermediates. Candidates are reminded that it is not sufficient to quote Markovnikoff's 'rule' by way of explanation.

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Paper 9701/22
AS Level Structured Questions

Key Messages

A sound knowledge and understanding of the basic ideas and definitions of all topics is important in order to achieve success at this level. Once a sound foundation of knowledge is established then these ideas can be further developed and linked in a relevant and logical manner.

General Comments

Many candidates demonstrated a good knowledge of the basic concepts and definitions assessed in this paper. Difficulty arose, for some, when ideas needed to be applied to new situations.

Knowledge of the formulae and appropriate names of compounds relevant to the syllabus, or the ability to work them out, is essential. This includes interpretation and representation of the different formulae used to represent organic compounds.

Comments on Specific Questions

Question 1

- (a) (i) Some candidates confused the reaction which occurs when magnesium reacts with steam with that with cold water and therefore equations showing the formation of magnesium oxide instead of magnesium hydroxide were given.

In some cases when the correct products were identified mistakes were seen when stating the formula of magnesium hydroxide or in attempts to balance the equation.

- (ii) The idea that the cloudiness arose due to the insolubility of the magnesium-containing product was often described.
- (b) (i) Many candidates correctly explained the increased reactivity down Group 2 in terms of increased atomic size and lower nuclear attraction for outer electrons resulting in a decrease in ionisation energy. Some answers incorrectly stated that more electrons were lost as Group 2 is descended.
- (ii) Description of appropriate observations was common. There was some confusion with the flame colour seen and occasional inappropriate use of the term *precipitate*. Omission or use of incorrect state symbols, an incorrect formula of magnesium oxide and incorrect balancing of equations were the common mistakes.
- (iii) The equation for the reaction of magnesium with sulfuric acid was well known. A small number of answers described water as a product while some showed confusion with the formula of magnesium sulfate.
- (iv) Many answers here were vague and gave an explanation of the trend in ionisation energy rather than the change in melting point. Few answers mentioned the metallic structure of Group 2 elements and the idea of delocalised electrons was rarely seen. Incorrect reference to intermolecular forces, van der Waals' forces and molecules were seen. Confusion over the term *thermal stability* was also noted.

Question 2

(a) There was a clear distinction between well-rehearsed answers to this definition when compared to those answers which showed only a general idea of its meaning. There were many confused responses which included omission of key details, use of inappropriate vocabulary, and muddling ideas; for example, comparing the mass of 1 mole of a formula unit to the mass of 1 atom of carbon-12.

(b)(i) The 'dot-and-cross' diagram of the ammonium ion showing three covalent bonds and a dative covalent bond was the common answer.

(ii) The correct shape and bond angle of the ammonium ion were seen in many responses.

(c)(i) In general there were good descriptions of a Brønsted-Lowry acid in terms of its ability to donate protons or hydrogen ions. Explanations of why the acid was weak presented greater difficulty. Confusion of the term *partially dissociating* with *partially dissolving* was seen.

(ii) This question proved to be challenging and many candidates struggled to apply the definition of a weak acid to an equation describing the behaviour of the ammonium ion when added to water. The use of the equilibrium symbol, \rightleftharpoons , was rare.

Omission of one or more charges on the ions formed, the use of $\text{H}_3\text{O}^+(\text{l})$ rather than $\text{H}_3\text{O}^+(\text{aq})$, and the addition of hydroxide ions, rather than water, were seen frequently.

(d)(i) The ability to balance the equation using oxidation numbers proved difficult. Many answers made no attempt to ensure that the overall charges on either side of the equation balanced.

(ii) The majority of answers correctly described the role of Fe^{2+} with an appropriate explanation. Some confused the term oxidising agent with reducing agent and there was occasional reference to the Fe^{2+} acting as a catalyst.

(iii) Correct calculation to find the amount of manganate(VII) ions in the reaction was often seen.

(iv) The use of the stoichiometry from the equation balanced in (i) and the amount of manganate(VII) calculated in (iv) were often used to calculate the amount of Fe^{2+} ions in the salt.

(v) Finding the relative formula mass of the hydrated salt presented difficulties for many. Only candidates who were able to fully interpret all the information provided in the question appreciated that the stated mass of the hydrated salt and the number of moles of salt used (deduced from (iv)) were required to find this formula mass.

Answers showing the formula mass of the anhydrous salt were common. Some candidates left this part unanswered.

(vi) Many of those who had produced an answer in (v) were able to use this value and the formula mass of water to find the value of x.

Question 3

(a)(i) The majority of answers correctly described the type of reaction as combustion. Cracking was the most common incorrect response.

(ii) Responses showing correctly balanced equations for the complete combustion of octane were common. Occasionally a correctly balanced equation for incomplete combustion was described.

(b)(i) Correct identification of the process was seen, but some identified the process as polymerisation or fractional distillation.

(ii) Although many answers appreciated the general structure of the polymer, some did not answer the question and showed more than one repeat unit.

(iii) Identification of addition polymerisation was well known.

- (c) (i) The majority of candidates stated that the catalytic convertor is used to remove gases from the exhaust of an internal combustion engine.
- (ii) The production of an equation, which described how carbon monoxide and nitrogen monoxide are both removed from the exhaust, proved challenging. Some equations showed nitrogen monoxide rather than nitrogen dioxide as a reagent, others described oxygen gas or nitrogen monoxide as a product. Other equations showed the correct reagents and products but were not balanced correctly.
- (iii) Although there are potentially many acceptable responses to this question, very few responses made reference to the formation of photochemical smog or global dimming.
- Some answers incorrectly stated that unburnt hydrocarbons damage the ozone layer.
- (d)(i) The consequences of acid rain were well known.
- (ii) The equations describing the formation of acid rain were generally well known.
- (iii) There was some difficulty expressing why nitrogen dioxide is described as a catalyst in the reaction. Many appreciated that nitrogen dioxide is regenerated by the reaction of oxygen gas with nitrogen monoxide. Not all equations were correctly balanced.

Question 4

- (a) (i) Stating the formula of tri-iodomethane did not gain credit as the question specifically asked for the **name** of the compound which formed as a yellow precipitate. Reference to the compound as iodomethane or including iodide or iodine in the name were common mistakes.
- (ii) Many correctly named **W** as butan(-2-)one. Some had difficulty describing the correct suffix and but-2-one, buta-2-one were seen. Others did not use the lowest number to describe the position of the C=O group in the carbon chain and identified **W** as butan-3-one.
- (b) Any unambiguous way of representing the two structures which are isomers of **W** was given credit. Candidates need to be aware that when drawing structural formulae care needs to be taken with appropriate connectivity to remove ambiguity when representing an aldehyde group rather than an alcohol group.
- (c) (i) Candidates were required to recognise the functional group of the organic reactant and the product involved in reaction 1 in order to identify this type of reaction as reduction. Many answered this correctly. Hydrolysis and hydration were common incorrect responses.
- (ii) Identification of the reagent used to convert butan(-2-)one to butan-2-ol was well known.
- (d) (i) Only a relatively small number of candidates were able to demonstrate a clear understanding of the details required when describing this reaction mechanism. The position of the curly arrow, from the start of the tail to the arrow head, should be carefully drawn to describe the movement of a pair of electrons, either from a lone pair of a covalent bond to an atom to create an ion, or to where a specific bond will be made.
- However, it was common to see the start of the arrow beginning at the negative charge of an ion rather than a lone pair or from an atom rather than a specific bond. Correct dipoles on the carbonyl group were seen, often alongside many other dipoles.
- Many answers incorrectly described the lone pair on the nitrogen atom of the CN^- ion attacking the carbon atom of the carbonyl group.
- (ii) The majority of answers deduced that **X** showed optical isomers and although the more general description of stereoisomerism was accepted, it was a less common response. There was occasional incorrect reference to cis- and trans- isomers.
- (iii) The idea of an asymmetric carbon atom was often described. Few answers included the idea that non-super(im)posable mirror images were produced.

- (e) (i)** Nearly all candidates could divide the percentage masses by the relative atomic masses in the first stage of finding the empirical formula and most then went on to divide by the smallest to get the correct ratio and thereby show the empirical formula of Y.

Some answers missed out the second step and optimistically rounded the numbers up to the correct answer.

- (ii)** Most candidates realised that the empirical formula mass was equal to the molecular formula mass.

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Paper 9701/23
AS Level Structured Questions

Key messages

Candidates should be reminded that in questions involving organic mechanisms, it is important to accurately show curly arrows starting from either a lone pair of electrons or directly from the middle of a σ or π covalent bond.

Candidates should ensure that terminology is used correctly, particularly in definitions.

General comments

Question 3(b) asked for an ionic equation and this proved challenging. Many candidates either did not read the question or were unfamiliar with the terminology or strategy to derive ionic equations and to include the correct state symbols.

The use of electronegativity when referring to the breaking of covalent bonds, in rate of reaction questions, was often irrelevant and led to incorrect conclusions regarding the rate of reaction of different halogenoalkanes.

Comments on specific questions

Question 1

- (a) Many answers received credit for the shape and name of SO_3 . Some candidates attempted 'dot-and-cross' diagrams of SO_3 ; these were credited providing they showed the correct shape. Diagrams of Cl_2O were less successful with several answers giving a linear shape, even when lone pairs were drawn on the oxygen atom.
- (b) (i) The concept of melting was challenging for many candidates, with several answers mentioning intermolecular forces of attraction in **ionic** compounds. Stronger attraction between the species in the structure of the oxides was quite well understood but a comparative statement for the reason behind this attraction being responsible for the difference in melting points, was often absent.
- (ii) A significant number of answers correctly stated that SiO_2 was a giant covalent structure but then continued to describe van der Waals' forces in both SiO_2 and SO_3 . The comparison between breaking actual covalent bonds, during the melting of SiO_2 , and the intermolecular attractions between SO_3 molecules was missed by most candidates.
- (c) (i) Many candidates appreciated that an increase in pressure resulted in more frequent collisions but did not recognise that this results from the particles becoming closer together. This increases the rate.

The position of equilibrium was frequently not clearly stated and so there were many ambiguous answers. The increased yield was often mentioned but with no indication as to the reason for the shift of the position of equilibrium.

- (ii) Generally this question was not well answered; answers should have referred to the concentration-time graph where the concentrations of the reactants are decreasing with time.

- (iii) There were many correct answers here referring to the establishment of equilibrium as a correct explanation as to why all three lines on the graph became horizontal.
 - (iv) This question was quite well answered but some candidates struggled to express themselves clearly, by not recognising from the equation in the stem of the question, that the ratio of $\text{SO}_2:\text{O}_2$ is 2:1.
- (d) (i) Many full-credit answers were seen with only a few answers incorrectly using round brackets or partial pressure annotations, for concentrations, in the equilibrium expression for K_c .
- (ii) This part was generally well answered although some candidates assumed that the moles of SO_3 , at equilibrium, given in the question, matched those of SO_2 which then resulted in an incorrect calculation for the amount of O_2 , at equilibrium.
 - (iii) Many candidates answered correctly in (d)(i) and (d)(ii) but did not change the amounts, in moles, to concentrations for use here.

Many answers for the units were correct but there were still a number of candidates who did not deduce the correct units from their correct equilibrium expressions.

A number of answers were not given to three or more significant figures, as per the values given in the stem of the question.

Question 2

- (a) (i) Many candidates were correctly able to give the first part of the definition of structural isomerism but struggled with expressions for different structural formulae, with several answers being confused with stereoisomerism.
- (ii) Similarly, many answers correctly stated that stereoisomers have the same structural formula but did not refer to a different spatial arrangement of the atoms/groups.
- (b) (i) Examiners were specifically looking for **one** reason describing the criterion for geometrical isomerism, where each C atom in the C=C double bond requires two different atoms/groups. A second reason is the lack of chirality in the molecule. Many answers correctly described the lack of chirality but a second reason involving the description of geometric isomerism was often confused and imprecise.
- (ii) There were many good answers to both the name and displayed formula. Common errors were the lack of a fully displayed formula or an incorrect name of the chain with 'pentene' often appearing in answers.
 - (iii) There were many very good answers with an occasional omission of the prefix cis/trans.

Question 3

- (a) (i) This question was well answered with most answers stating that the volatility decreases down Group 17.
- (ii) The explanation of the trend in (a)(i) was less well answered. Statements regarding electronegativity, size of atoms and shielding arguments frequently appeared. The two themes of increasing number of electrons, down the group, accompanied by increased intermolecular forces of attraction, needed to be mentioned.
- (b) This question was well answered by most candidates.
- (c) (i) This part was quite well answered by many. Common errors included giving formulae instead of names for the precipitates and incorrect descriptions of the colour of the silver chloride precipitate.
- (ii) This question was not well answered. Many candidates gave a full equation with the correct state symbols but were then unable to convert to an ionic version of the same equation, with state symbols.

- (d) The question required statements referring to the difference in reducing ability of the HCl and HI or the converse argument using the difference in the ability of H_2SO_4 to oxidise HI but not HCl .

Many answers referred to the ability of H_2SO_4 to oxidise both Cl^- and I^- but then continued to state that further reductions occurred with I^- and H_2SO_4 but not with Cl^- .

The most common error was to refer to the elements chlorine and iodine when describing reaction(s) with H_2SO_4 rather than the hydrogen halides or halide ions.

An equation to represent the reaction of sulfuric acid with NaCl or the behaviour of H_2SO_4 as an acid here was rarely seen.

- (e) (i) Generally this question was well answered and the requirement for an oxidising agent to accept electrons was generally recognised.
- (ii) There were many correct answers to this part. The most common error was the omission of HCl as a product.
- (iii) There was a small number of high scoring answers involving the equation for Cl_2 with hot $\text{NaOH}(\text{aq})$ to give NaCl and NaClO_3 , followed by correct explanations for chlorine being involved in a redox reaction.

Some answers gave incorrect equations, often involving NaCl and NaClO or HClO as products, but still gave answers that correctly assigned oxidation numbers to Cl indicating redox behaviour.

Question 4

- (a) (i) Many candidates were able to give the correct name of **A** as 2-bromobutane.
- (ii) There were several correct answers to this question where a secondary alcohol was oxidised to give a ketone, the class of compound to which **B** belongs.

Common errors referred to alcohol and alkyl halide.

- (b) Several answers included two correct isomers of **A**, but the third isomer proved elusive with many answers giving 2-bromobutane, **A**, as one of the isomers.
- (c) (i) Many full-credit answers were seen correctly identifying the letters S and N as representing substitution and nucleophilic.
- (ii) Many answers appeared to imply that there was some confusion between $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ mechanisms. Several answers contained a combination of both.

Other common errors included incorrect use of curly arrows which either did not originate from a lone pair of electrons or originated from the middle of a σ or π covalent bond.

- (d) This question was not well answered. A significant number of answers referred to $\text{CH}_3\text{CHClCH}_2\text{CH}_3$ as having the higher rate of reaction, compared to $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$, relating this to the high electronegativity of the Cl atom. Similarly many answers referred to $\text{CH}_3\text{CHICH}_2\text{CH}_3$ as having the slowest rate of reaction, again because of the low value of the electronegativity of I . Both arguments appear to suggest that candidates consider bond polarity the key issue in bond breaking rather than bond energies.

Those answers that referred to bond energies, rather than electronegativity, tended to receive credit.

- (e) Several answers recognised that one difference in the conditions was the requirement for ethanol as a solvent.

The comparative temperature difference was frequently not mentioned.

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Paper 9701/31
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to read through the paper, highlighting key points and preparing tables for data, before starting any practical work.
- Candidates should be given the opportunity to practise key techniques and be encouraged to use the terminology given in the Qualitative Analysis Notes accurately.
- Candidates should think how to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.
- Candidates should be reminded to write their answers in black or dark blue pen rather than faint pencil.

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:

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results.

Nearly all candidates completed the paper so that there was no evidence that lack of time was a factor in overall performance.

Comments on specific questions

Question 1

The vast majority of candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation.

- (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 readings taken for the accurate titres. Candidates should record accurate burette readings to 0.05 cm^3 . Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres. Almost all candidates gained at least partial credit for accuracy and a significant number were awarded full credit.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 2** to be used in the calculation. The most common errors were not displaying the answer correct to two decimal places or not showing clearly how the value was obtained.
- (c) There were some excellent answers to this section showing that some centres had prepared their candidates well. The commonest error was giving answers to an inappropriate number of significant figures – since all data was given to 3 significant figures, answers corrected to 3 or 4 were accepted.

Question 2

In the calculation part of this question many candidates made errors that meant that their answers were chemically not possible. However this did not mean that further credit later in the question dependent on these values, was not available. It is important therefore that candidates do not give up when unlikely answers are found even though, of course, ideally they should consider why they have an obviously erroneous answer.

- (a) As in **Question 1**, most candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation.
- (b) (i) Most candidates calculated the number of moles of hydrochloric acid correctly and realised that the number of moles of sodium hydroxide would be the same.
- (ii) There were many correct answers of the number of moles of sodium hydroxide added to **W** but far fewer candidates recognised the need to multiply their answer to (i) by 10 to find the number of moles that remained after the reaction with **W**.
- (iii) Only a minority of candidates gained credit as a number did not carry out the relevant subtraction and/or did not divide the answer obtained by 2.
- (iv) Most candidates correctly calculated a value for the M_r of **W** using their answer to (iii).
- (v) This is an example of where some candidates had values that were chemically most unlikely/impossible but many gained credit when they used their values in a sensible manner to identify **X**.
- (c) This part was only answered correctly by a few candidates. Even though the question stated that possible errors in the volumes should not be considered and burettes and pipettes were used in the exercise as set, many candidates suggested the use of these pieces of apparatus in some way.
- (d) For this question it was necessary to realise that the differences in the A_r s of the halogens must be considered and that these differences are not the same for all of them.

Question 3

Some candidates would benefit from learning precise definitions of terms such as 'precipitate', 'solution', 'soluble' and 'insoluble'. It is clearly incorrect, for example, to state that a 'soluble precipitate' is formed. Candidates should also recognise that 'no observation' is not an acceptable statement when 'no (visible) reaction' or 'no (observable) change' is correct.

- (a) (i) Most candidates observed bubbles/effervescence with sodium carbonate but few went on to identify the gas formed. This is in spite of the very clear instruction, in the information at the start of the question, that any gas formed should be identified.
- In a test, such as that with acidified potassium manganate(VII), where a colour change is observed, candidates are advised to state the initial and final colour involved.
- (ii) A significant number of correct functional groups were identified but, if an alcohol was suggested, it was necessary to state that the alcohol must be primary or secondary.
- (b) (i) Most candidates again observed fizzing and then went on to consider the effects of adding both a small volume and then excess aqueous sodium hydroxide. A number however stated that the initial white precipitate, formed with the sodium hydroxide, was insoluble in excess reagent.
- (ii) Most candidates noted that a blue precipitate was formed but credit was not awarded if a dark blue precipitate was suggested. On heating this precipitate its colour changes and darkens and this was generally observed. A large number of candidates noted the formation of a gas but again a significant number did not actually give a positive test for the ammonia formed.
- (iii) Many candidates correctly identified the cations but, although the use of aqueous ammonia as a test to choose between aluminium and zinc was often suggested, a number did not gain credit as

they did not make it clear that it was the precipitate that was originally formed in the test whose solubility in excess reagent needed to be observed.

- (iv) Many correct answers were given here, showing that candidates had made correct observations and used the Qualitative Analysis Notes appropriately.

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| <p>Paper 9701/32 Advanced Practical Skills 2</p> |
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Key messages

- Candidates should be encouraged to read through the paper, highlighting key points and preparing tables for data, before starting any practical work.
- Candidates should be given the opportunity to practise key techniques and be encouraged to use the terminology given in the Qualitative Analysis Notes accurately.
- Candidates should think how to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements. These considerations should include the accuracy to which measurements on different pieces of apparatus should be read.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.
- Candidates should be reminded to write their answers in black or dark blue pen rather than faint pencil.

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:

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results.

Nearly all candidates completed the paper so that there was no evidence that lack of time was a factor in overall performance.

Comments on specific questions

Question 1

The vast majority of the candidates successfully completed the practical work although it should be noted that the use of spirit burners is not suitable for experiments in which quantitative thermal decomposition is required. If a piped gas supply is not available, the use of butane/propane burners is a satisfactory alternative.

- (a) Most candidates recorded their results in a suitable format but a number used 'weight' in place of 'mass', did not calculate the masses of **FB 1** used and/or the residue obtained or calculated these masses incorrectly.
- (b)(i) The majority of candidates used the correct data to calculate mean masses but a significant number ignored the instruction to give answers to two decimal places.
- (ii) It was expected that candidates would use their answers to (i) to calculate the mean number of moles of water lost and many did. Calculations based on using values from the table were also accepted.

- (iii) Some candidates appeared confused about which mass they should use but most recognised the relationship needed in order to calculate the relative formula mass.
 - (iv) Many candidates used their calculated value of the relative formula mass to calculate the relative atomic mass of **M**. The identification of **M** was credited if it was the Group 2 element with the closest A_r to this calculated value. A number of candidates suggested elements that had a close A_r but which were not in Group 2.
- (c) (i) A number of candidates correctly described the need to heat and cool to achieve constant mass. It is however not acceptable merely to suggest that the crucible should be heated for a longer time.
- (ii) A significant number of candidates realised that the presence of the carbonate contamination would mean that carbon dioxide would be produced but fewer realised that the A_r calculated would be smaller because the carbon dioxide released would have a greater mass than the water released by a corresponding mass of hydroxide.

Question 2

Throughout this question answers to calculations were accepted that were correct to 2, 3 or 4 significant figures. Most candidates gave answers within this criterion but a few simplified answers to 1 significant figure or claimed accuracy greater than 4.

- (a) (i) As in **Question 1** most candidates successfully completed the practical but many did not read the thermometer to the correct degree of accuracy. Since the thermometer was graduated to $\pm 1^\circ\text{C}$, readings should be recorded to end in .0 or .5 $^\circ\text{C}$.
- (ii) Most candidates were clearly familiar with the use of $mc\Delta T$ but a few incorrectly used the mass of calcium hydroxide as m .
- (iii) Most candidates correctly calculated the number of moles of **FB 3** used with only a small minority using 74 as the M_r . The Periodic Table printed in the question paper clearly indicates that 74.1 should be used.
- (iv) Once again, most candidates were clearly familiar with the calculation needed.
- (b) It was expected that a larger increase in temperature than that seen in (a) would be recorded. This proved generally to be the case but credit was awarded for smaller values if the supervisor's results indicated that this was appropriate.
- (c) To gain full credit it was necessary, as given in the question instructions, to draw a Hess' Law energy cycle but some credit was given to candidates who calculated a correct answer without doing so.
- (d) Many candidates gave an acceptable answer to (i) but far fewer realised, in (ii), that the presence of acid in excess meant that the temperature rise would be the same. A large number of answers were based on the idea that a greater concentration would give more collisions and a resulting larger temperature increase.

Question 3

Some candidates would benefit from learning precise definitions of terms such as 'precipitate', 'solution', 'soluble' and 'insoluble'. It is clearly incorrect, for example, to state that a 'soluble precipitate' is formed. Candidates should also recognise that 'no observation' is not an acceptable statement when 'no (visible) reaction' or 'no (observable) change' is correct.

- (a) Several of the tests involved the formation of a gas. The observation of fizzing or bubbles or effervescence was often given but, in many cases, no attempt was made to identify the gas produced. This is in spite of the very clear instruction, in the information at the start of the question, that any gas formed should be identified.

This information also includes the instruction that 'no additional tests for ions present should be attempted'.

Candidates should be advised to be careful in their description of the colour of precipitates and solutions.

- (b)(i)** Many candidates gave Ag^+ as the cation in **FB 7**.
- (ii)** The ionic equation between magnesium and (aqueous) hydrogen ions was given correctly by only a few candidates. Many equations included the whole formulae of reacting substances.
- (iii)** This type of reaction was generally not recognised. The most common answers seen were displacement or redox.
- (iv)** The ionic equation for the precipitation reaction specified was better known than that in **(ii)** although a number of answers omitted state symbols or included incorrect symbols.

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Paper 9701/33
Advanced Practical Skills 1

Key messages

Candidates should be encouraged to read through the paper, highlighting key points and preparing tables for data, before starting any practical work.

Candidates should be given the opportunity to practise key techniques including those generating graphs and should be reminded that lines of best fit may be straight or a smooth curve.

Candidates should be encouraged to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements.

Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper. This is particularly important where centres are sharing a venue.

Candidates should be reminded to write their answers in black or dark blue pen rather than pencil.

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:

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results.

Comments on specific questions

Question 1

The vast majority of the candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation.

- (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 readings taken for the accurate titres. Candidates should be reminded to record accurate burette readings to 0.05 cm^3 . Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent unnecessary titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres. Almost all candidates gained at least partial credit for accuracy and a significant number gained full credit.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 1** to be used in the calculation. The most common error was not displaying the answer correct to two decimal places.
- (c) There were some excellent answers to this section. A significant minority did not appreciate the mole ratio of NaOH to H^+ . The most common error was to give the answer to part (iii) to 1 or 2 significant figures thus ignoring the level of precision given in the question. Since all data was given to 3 significant figures, answers corrected to 3 or 4 s.f. were accepted.

Question 2

Most candidates made a good attempt at this question although the graph proved to be more difficult. Candidates should be encouraged to mark points with thin, small diagonal crosses centred in the correct position.

- (a) Most candidates gained credit for unambiguously recording the results although some omitted the initial temperature from their table. The precision with which the thermometer readings were recorded tended to be centre dependent. A thermometer with graduations at 1°C should be read to the nearest 0.5°C so **all** readings should end with .0 or .5. The accuracy with which the experiment was carried out was good with most candidates gaining at least partial credit.
- (b) Candidates who used sensible scales were more likely to gain credit in (b) and (c). A significant minority either ignored the requirement that the y -axis should include a temperature 2°C above the highest temperature reached in the experiment or did not use at least half the plotting area. Candidates should be encouraged to plot points accurately. Points that should be on a line must be on that line, points that should be in a small square should be in the correct part of the small square. Some candidates did not include the initial temperature of **FA 4** and many did not indicate anomalies even when the points lay a long way from any possible line of best fit. The data for the left-hand best fit line often fitted a smooth curve but very few candidates attempted to draw one. Almost all candidates were successful in extrapolating their lines of best fit to a discontinuity.
- (c) There were many correct answers seen though some candidates interpreted their own scales incorrectly or used values from their tables of results.
- (d) Only a minority of candidates gained credit in part (i) as most candidates did not add the volume of **FA 3** at the discontinuity to the 25 cm^3 of **FA 4**. A large majority of candidates answered part (ii) successfully and most went on to provide a correct answer in (iii) from their values in (i) and (ii).
- (e) Few correct answers were seen here. Although some candidates suggested taking the temperature on adding smaller volumes of **FA 3** only a few wrote that this is only needed near the maximum temperature.
- (f) Most candidates understood the difference that strong and weak acids would have on the enthalpy of neutralisation. However, some did not link the units of kJ mol^{-1} with the formation of 1 mole of water from $\text{H}^+(\text{aq})$ and $\text{OH}^-(\text{aq})$ and therefore suggested that acid **X** was less concentrated. While some candidates went on to explain the difference in value such as 'to ionise the acid' few specified that energy was needed to break the bond between H and the rest of the molecule in acid **X**.

Question 3

Candidates should be encouraged to read and follow the instructions carefully: the volumes of reagents used are frequently critical. Some candidates would benefit from learning precise definitions of terms such as 'precipitate', 'solution', 'soluble' and 'insoluble'.

- (a) Better answers specified that only two reagents were needed to distinguish between the three acids. The majority of candidates gained at least partial credit in this section though very few gained full credit. Many candidates omitted a test for distinguishing the different concentrations of hydrogen ion in the three acids tested. Most gave the correct names and/or formulae for one or more of the possible reagents for distinguishing between the sulfuric and hydrochloric acids. Most of these candidates went on to gain credit for observations with aqueous barium chloride (or nitrate) and/or aqueous silver nitrate. Centres should be reminded that 'no observation' is not the same as specifying that no visible change occurred. Some of those testing the two sulfuric acid solutions with sodium carbonate or magnesium ribbon did not report that there was slower bubbling with **FA 4** than with **FA 5**. Credit was given to those suggesting the use of a pH indicator and adding drops of aqueous sodium hydroxide provided equal volumes of the two solutions were specified. Those selecting appropriate reagents and obtaining the expected results went on to gain credit for the conclusions.

- (b) Not all candidates added sodium hydroxide and ammonia reagents to excess, which should always be done in such tests. The tests with universal indicator were generally successful though not all candidates included both colour and pH value in their responses. The heating test was generally poorly answered: few candidates recorded the condensation formed on warming **FA 8** or the sublimation of **FA 9**. However, many gained credit for the gas turning red litmus blue on warming **FA 9**. Some candidates also recorded a gas turning blue litmus red but did not make clear that this was on further or stronger heating of **FA 9**. It was rare to award full credit in part (iii) as, although many candidates concluded **FA 9** contained the ammonium ion, few concluded magnesium in **FA 8**.

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Paper 9701/34
Advanced Practical Skills 2

Key messages

- Candidates should be encouraged to read through the paper, highlighting key points and preparing tables for data, before starting any practical work.
- Candidates should be given the opportunity to practise key techniques including those generating graphs to appreciate that lines of best fit may be straight or a smooth curve.
- Candidates should be encouraged to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper. This is particularly important where centres are sharing a venue.
- Candidates should be reminded to write their answers in black or dark blue pen rather than faint pencil.

General comments

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

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results.

Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

The vast majority of candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation. However, the graph and related questions were not so well answered. Candidates should be encouraged to plot points with thin small diagonal crosses centred in the correct position.

- (a) A large majority of candidates provided a table for five experiments with the three sets of data and two sets of calculations arising. Most were able to provide unambiguous headings though some left out a unit for rate. Many candidates either did not give sufficient precision of the thermometer reading (all readings should be to .0 or .5 °C) or ignored the instruction to record times to the nearest second. Where candidates select temperatures at which to carry out further experiments the expectation is that they will select a range of temperatures that are as different as possible from each other and from those specified in the question paper. As the smallest difference in initial temperature between **Experiment 1** and **Experiment 2** was 30.0 °C it should have been straightforward for the initial temperatures for **Experiments 3, 4** and **5** to be at least 5.0 °C apart. Most candidates correctly calculated the mean temperature though some omitted this section and some disregarded the instruction to give the mean to 1 decimal place. The calculation of the rate was carried out successfully by many candidates: the most common errors were due to incorrect rounding or in only giving the rate to 1 significant figure. Almost all candidates gained credit for an increase in rate (or decrease in time) with increase in temperature. A large majority gained credit

for the increasing gradient with increase in temperature even when the 'line of best fit' drawn was straight.

- (b) Candidates generally selected suitable scales so their graphs occupied more than half the grid. Some mistakenly started the x-axis at 30.0 °C, some included negative rates on the y-axis, and a significant minority selected scales that meant it was difficult to plot points. Candidates should be encouraged to plot points accurately. Points that should be on a line must be on that line, points that should be in a small square should be in the correct part of the small square. Very few candidates drew the expected smooth curve of best fit even though their plotted points made a curve the obvious choice.
- (c) Candidates were expected to draw two lines, one vertically from 52.5 °C to meet the line of best fit and the other horizontally to the y-axis. A majority of candidates gained at least partial credit here but calculating the time proved to be more problematic. The most common errors were not converting the rate to time and ignoring the instruction to give the time to the nearest second. Candidates should be aware that a time of 34.0 s is to the nearest tenth of a second and is not an integer.
- (d) Almost all candidates were awarded credit for the first marking point. Many candidates then referred to collision theory rather than to their graphs so could not be awarded further credit.
- (e) There were some excellent answers to this section. A large majority of candidates gained credit in (i), the most common error being in giving the answer to an inappropriate number of significant figures. Most of those setting out their working clearly and showing appropriate units gained credit in (ii). The vast majority of candidates showed oxidation products for at least one of the aldehyde, primary or secondary alcohol groups in glucose. The most common error was to give aldehydes or carboxylic acids as the oxidation product of the secondary alcohol groups.
- (f) There were many correct answers to part (i) though a significant minority doubled the error, did not use the time for **Experiment 1** or gave the answer to one significant figure. The answer to part (ii) needed to be specific to the candidate's results and include a reason for the choice. For example, 'Repeat Experiment # as it was anomalous' was insufficient; reference was needed to the point being furthest from the line of best fit.
- (g) The most common correct answer was to use burettes or pipettes to measure all volumes. Slightly less common was to use a thermostatically controlled water bath with the use of a colorimeter.

Question 2

Some candidates appeared unsure of the distinction between 'solution' and 'precipitate': for example, 'soluble' was used to describe adding one solution to another. Candidates should also recognise that 'no observation' is not an acceptable statement when 'no (visible) reaction' or 'no (observable) change' is correct.

- (a) The majority of candidates gained at least partial credit in part (i). The most common errors were not giving the initial colour of the potassium manganate(VII) when reacting with **FB 5**, reporting inappropriate colours for the aqueous iodine and not reporting a precipitate when Sandell's solution was heated with **FB 5**. The vast majority of candidates gained credit in part (ii) and most candidates selected either Tollens' reagent or acidified potassium dichromate(VI) with suitable expected observations in part (iii). The most common error here was the choice of 2,4-dinitrophenylhydrazine. Fehling's reagent and acidified potassium manganate(VII) were also seen.
- (b) Care must be taken in distinguishing the colour of a precipitate in a coloured solution as the precipitate formed by aqueous barium nitrate (or chloride) with **FB 7** was frequently described as blue. Many candidates missed the precipitate on adding aqueous iodine to **FB 7** and wrongly described the precipitate formed on adding **FB 8** to **FB 7** as deep or dark blue. The most popular choice of equation in part (iii) was for the reaction between aqueous barium ions and aqueous sulfate ions. Other popular choices were aqueous iron(II) or copper(II) ions with aqueous hydroxide ions. Some candidates did not give state symbols and some confused writing a half equation instead of an ionic equation for a precipitation reaction they had recorded in part (i).

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| <p>Paper 9701/35 Advanced Practical Skills 1</p> |
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Key messages

Candidates should be encouraged to read through the paper, highlighting key points and preparing tables for data, before starting any practical work.

Candidates should be given the opportunity to practise key techniques including those for qualitative analysis and be given appropriate feedback with the help of past papers, mark schemes and examiner reports.

Candidates should be encouraged to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements.

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

Candidates should be reminded to write their answers in black or dark blue pen rather than pencil.

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:

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

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results.

Almost all candidates completed the paper indicating that there were no time constraints. It was evident that some candidates were more practised in the techniques than others from different centres. Practical work, whether individual, group or teacher-led tasks should comprise 20% of teaching time for this syllabus.

Comments on specific questions

Question 1

The majority of the candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation. Candidates from some centres appeared unpractised in this basic technique.

- (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 readings taken for the accurate titres. Candidates should be reminded to record accurate burette readings to 0.05 cm^3 . Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent unnecessary titration. Many candidates completed the titration well with correctly headed tables for data and clearly presented readings and titres. Almost all candidates gained at least partial credit for accuracy and a significant number gained full credit.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 2** 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 some excellent answers to this section showing that some centres had prepared their candidates well. Candidates need to consider the precision of data given in the question and provide a numerical answer that is given to the same number of significant figures or one more

significant figure than the data provided unless otherwise instructed. Since all data was given to 3 significant figures, answers corrected to 3 or 4 s.f. were accepted. Most candidates correctly calculated the number of moles of acid used in (ii) and the majority used the mole ratio correctly in (iii) and thus correctly calculated the moles of sodium carbonate. However, many candidates ignored the instruction to include state symbols when completing the equation so were unable to be awarded credit. Candidates were more successful in (iv) though some did not include the factor of 10 between volumes of pipette and volumetric flask. The majority of candidates reaching this point successfully calculated the M_r value of anhydrous sodium carbonate and hence the value of x in the hydrated compound. Not all candidates noted the instruction to give the answer as an integer.

- (d) Although a large number of candidates noted that hydrochloric acid is monoprotic while sulfuric acid is diprotic some confused this with strength of acid. The link between percentage error in measuring volume doubling owing to a halving of volume of acid was not appreciated by many candidates.

Question 2

Some candidates struggled with displaying data or with the calculation.

- (a) Many candidates gained credit for the headings and units of the tables though a number labelled the residue as 'FA 4 after heating'. This was inappropriate as FA 4 was the designation of the hydrated compound. Almost all candidates weighed out a mass of FA 4 within the range specified in the question but some candidates confused the mass of residue with the mass of water lost.
- (b) Many candidates obtained full credit here. Almost all candidates gained credit in part (i) for calculating moles of water lost. However, some of these did not go on to divide their answer by 7 in (ii). Many candidates showed correct working in (iii) and most of these calculated the formula mass of SO_4^{2-} from the values in the Period Table supplied. Many candidates did not use the initial information regarding Y with a number of them suggesting elements that had a close A_r but which were not in Group 2. However, many gained credit by selecting the Group 2 metal consistent with their answer in (iii).
- (c) Candidates who referred to the method of calculation in (b) usually gained full credit. However, some candidates did not explain their answers in sufficient detail.

Question 3

Candidates should be encouraged to read and follow the instructions carefully: the volumes of reagents used are frequently critical. Candidates should be encouraged to record all changes they see. Centres should be reminded that 'no observation' is not the same as specifying that no visible change occurred.

- (a) The vast majority of candidates gained at least partial credit in part (i) for selecting aqueous sodium hydroxide and aqueous ammonia. The most common error was to not add the aqueous alkalis in excess and hence be unable to record the solubility of the white precipitates in this situation. Many candidates concluded that FA 4 contained the Mg^{2+} ion from their results in (i) but could only access credit for part (ii) if they stated whether this confirmed or nullified their choice of Group 2 metal (cation) in 2(b)(iv).
- (b) Gentle initial heating was required in part (i) for candidates to see condensation further up the test-tube. Few candidates tested for gases, though those selecting litmus papers or limewater were generally successful. Few candidates recorded a change in colour of the solid. There were some excellent answers to part (ii), however some candidates were unable to gain credit. Those who did not follow the instruction to add only a few drops of aqueous acidified potassium manganate(VII) to the fresh 1 cm portion of FA 5 were disadvantaged as this made the observation with aqueous ammonium thiocyanate more difficult. Some candidates reported the formation of a precipitate after this addition which should not have occurred. Most candidates also ignored the instruction at the beginning of the question to identify any gas formed by a suitable test. Aqueous hydrogen peroxide given as a reagent should alert candidates to the possibility of testing for oxygen so they have a wooden splint ready for use. Candidates were more successful in part (iii) in identifying the presence of Fe^{2+} and SO_4^{2-} in FA 5. However, fewer gave sufficient information in (iv) to be awarded credit. If only one of oxidation and reduction is given then the species being oxidised/reduced must be specified.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out, and never overwritten with the new answer.
- Candidates should take care drawing three-dimensional tetrahedral and octahedral diagrams and use wedged and hashed bonds as appropriate.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

- (a) Most candidates were awarded full credit for this equation.
- (b) Many candidates were awarded at least partial credit here. Statements about strong bonding should have specified that it was *between oppositely charged ions*, or some equivalent statement.
- (c) (i) Many candidates did not appreciate that the question asks why the *solution* is alkaline, and instead they used the Brønsted-Lowry theory to explain why Na_2O is basic.
- (ii) This calculation was done well by many. A common error was to calculate 0.05 moles of Na_2O and then to calculate $[\text{OH}^-]$ to be $0.125 \text{ mol dm}^{-3}$.
- (d) This lattice energy calculation included the need to double the two data values for Na, and to halve the data value for the O=O bond energy. Many candidates completed this difficult calculation successfully. Candidates should be reminded to show their working as this means that where an incorrect answer is given, it may be possible to award some credit for the method used.
- (e) The correct box was usually ticked, but a full explanation was seen much more rarely.

Question 2

- (a) Candidates' wording should be precise when definitions are asked for.
- (b) Candidates found this question difficult. Many candidates believed that a colour change would be involved or suggested that the amounts of reactants or products could be monitored. This would be extremely difficult to do in practice. However some candidates correctly realised that there would be a change in either total pressure or total volume, depending on the apparatus used.
- (c) Candidates generally received full credit for this question.
- (d) This question was usually fully credited.
- (e) This question was usually fully credited.
- (f) (i) This question was usually fully credited.
- (ii) Many answers were seen that were descriptions of a rate-determining step, such as 'this is the slow step', without actually explaining the reason for the answer in (f)(i). However a small number of excellent answers were seen, linking the $[\text{NO}]^2$ in the rate equation with N_2O_2 in step 2, clearly explaining this link, and including the involvement of one H_2 molecule in step 2.
- (g) (i) Candidates mostly knew the term half-life and gave precise definitions.
- (ii) Full credit was often awarded. Some candidates plotted a concentration of 0.0 mol dm^{-3} after four seconds.
- (h) (i) This discriminated well. Errors seen included equations involving N_2 or SO .
- (ii) Many inadequate answers were seen here, referring to the NO as 'not used up' or 'speeding up the reaction'. In this specific example the key observation is that the NO is involved in a chemical reaction, but it is subsequently regenerated.
- (iii) This was generally well answered.

Question 3

- (a) This was not well answered. The polarities of the anode and cathode were often misunderstood, and the ions discharged were often specified rather than the substances liberated.
- (b) (i) Many answers started with Ca and I_2 rather than Ca^{2+} and I^- .
- (ii) Candidates who had answered (b)(i) correctly usually answered this well, although some did not give reference to oxidation numbers.
- (iii) The production of a solid or liquid was often referred to, but mention of the evolution of a purple gas or vapour was much rarer. Candidates are not required to know the melting temperature of calcium iodide, but they should have deduced that an ionic solid such as this melts at a temperature well above the sublimation temperature of iodine.
- (c) There were many good answers to this question, using a wide variety of valid mathematical methods to reach the answer. No credit was given for Fe^{3+} unless supported by a correct calculation based on the data given in the question.

Question 4

- (a) The observations of heating calcium and barium in oxygen were not well known by many candidates.
- (b) Many candidates gained full credit here, although some did not refer to the decomposition temperatures, but instead made a statement about the stability of the compounds.
- (c) This discriminated well. Many good answers were seen in which the importance of the invisible nature of the gaseous product and the lack of colour change in the solid present were both appreciated and described.

Question 5

- (a) Most candidates answered this well.
- (b) Very rarely was full credit awarded here. The commonest error was in not appreciating that a linear complex must have the structure $Cl-Cu-Cl$; many square planar or tetrahedral complexes with composition $CuCl_4$ were seen. A significant number of candidates worked out the charge on the complex on the basis of Cu^{2+} not Cu^+ .
- (c) Most candidates correctly gave the name of the shape as octahedral, but a significant number missed the instruction to 'Label and state the value of one bond angle.'
- (d) There were many errors here, including:
unbalanced equations
not starting reaction 2 with substance **A**, which should be $Cu(OH)_2$ or $Cu(OH)_2(H_2O)_4$
not specifying that the product **B** is a solution.
- (e) (i) Candidates often gave the correct answer here.
- (ii) Many candidates gained credit here. The most common error seen was the putting of ionic charges outside the final set of square brackets, e.g. $[CuEDTA]^{2-}$ rather than $[[CuEDTA]^{2-}]$ or $[CuEDTA^2]$. Either $[[CuEDTA]^{2-}]$ or $[CuEDTA^2]$ is necessary because it represents the concentration of the complex.
- (iii) Credit was usually awarded for the statement ' $CuEDTA^{2-}$ is stable'; there were also a number of very specific and accurate answers that stated that ' $CuEDTA^{2-}$ is more stable than $[Cu(H_2O)_6]^{2+}$ '.
- (f) (i) A few candidates did not receive full credit but most had learned this definition.
- (ii) This was often answered well. Good answers showed correctly the formula and charge of the complex described, and explained that since ethanedioate is bidentate the zirconium ion has a co-ordination number of eight, whereas octahedral complexes have a co-ordination number of 6.

Question 6

- (a) (i) This was usually answered well. Common errors for **D** included 1-chloropropane and incorrect naming such as 'dimethyl chloromethane'.
- (ii) Many candidates gained credit, although a significant number gave 'Friedel-Crafts' without 'alkylation', and so credit could not be awarded.
- (b) (i) Many candidates gained credit here. It should be noted that answers including water, e.g. ' $C_2(aq) + AlCl_3$ ' did not receive credit as $AlCl_3$ would be hydrolysed.
- (ii) This was well answered.
- (iii) Many candidates gave a correct answer.
- (iv) Many candidates drew two identical substances, one with the chlorine atom on the left hand methyl group and one with the chlorine atom on the right hand methyl group, perhaps not realising that

these represented the same molecule. Some candidates had difficulty showing their answers with correct skeletal formulae, and drew $C_6H_5CHClCH_3$. The answers expected were $C_6H_5CCl(CH_3)_2$ and $C_6H_5CH(CH_3)CH_2Cl$. However if the two optical isomers of $C_6H_5CH(CH_3)CH_2Cl$ had been drawn correctly, using three dimensional bonds, this was also credit-worthy.

- (c) The reduction reaction was better known than the oxidation reaction.
- (d) This was quite discriminating. Many good, accurate structures were drawn for the intermediate and curly arrows were often drawn correctly and accurately. Some candidates did not take advantage of the diagram of cumene on the left, with space next to it. It was hoped that this would be used to show the original attack, by a pair of electrons from the ring, towards the NO_2^+ ion.

Question 7

- (a) This was often answered well, although many unbalanced equations, and equations with H^+ as product, were seen.
- (b)(i) This discriminated well.
- (ii) This also discriminated well. For each substance a clear statement of either how and why the anion is stabilised or destabilised or how and why the O–H bond is strengthened or weakened was required.

In order for full credit to be awarded, the relative acidities of any two of the three substances had to be explained correctly. Many statements were seen that described resonance, or stated something such as 'the oxygen lone pair resonates round the benzene ring'. It was often difficult to award credit here due to lack of clarity of the description. Statements such as 'one lone pair on the oxygen atom is delocalised into the benzene ring' (for the phenoxide ion) or 'the negative charge is delocalised between the two oxygen atoms' (for the propanoate ion) are much clearer.

- (c) Credit could not be awarded for
tests that are based on acid strength alone
suggesting the iodoform test
naming a correct reagent without describing the observations that would be made.
- (d) The propanoyl chloride and the reagent were usually identified correctly. Many candidates did not describe the generation of the phenoxide ion before adding the propanoyl chloride.
- (e)(i) Most candidates were awarded credit here.
- (ii) Many candidates chose to state that propan-1-ol has an absorption between 0.5 and 6.0 due to the OH proton, and propanal has an absorption between 9.3 and 10.5 due to the CHO proton, and so received full credit. Other correct answers, based for example on splitting patterns, were possible but more difficult and sometimes required careful wording.

Question 8

- (a) Candidates were generally able to identify the chiral carbon atom.
- (b) This question combined reduction with molecular formula calculation and proved to be difficult for most candidates.
- (c)(i) Candidates needed to recognise that the three C=C bonds will undergo oxidative cleavage, and then draw the skeletal formula of the correct molecule. Many found this difficult.
- (ii) and (iii) Candidates first had to deduce that initially the two smaller products are CH_3COCO_2H and HO_2CCO_2H . Then they had to remember that HO_2CCO_2H will be oxidised further to CO_2 .

Question 9

- (a) This discriminated well. Some candidates submitted formulae that were partly structural, which were not awarded credit.
- (b) Most candidates recognised the presence, and relevance, of a chiral carbon atom in noradrenaline.
- (c) (i) Many answers suggested that the reaction with phenylamine produces a stable diazonium ion due to delocalisation of lone pairs from the $-N_2^+$ group into the ring. However since this group is positively charged this would not help to stabilise it. Other answers were seen pointing out the ion is stable at 5°C , however it is stated that both reactions are performed at 5°C .
- (ii) N_2 as unreactive gas product was credited more often than the organic compound.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out, and never overwritten with the new answer.
- Candidates should take care drawing three-dimensional tetrahedral and octahedral diagrams and use wedged and hashed bonds as appropriate.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

- (a) This was generally well answered. Some candidates did not give the type of structure for SiCl_4 and did not specify the type of intermolecular forces.
- (b) (i) This was usually well known. Common errors seen were equations involving Si(OH)_2 and SiOCl_2 .
- (ii) The observations were generally correct.
- (iii) There were some common errors in the calculations involved in this question: answers of 1.70 (omission of division by 0.8), 1.90 (use of $\times 2$ not $\times 4$) and 2.2 (omission of $\times 4$).
- (c) (i) Most candidates gave the correct answer.
- (ii) Many candidates were able to clearly describe this explanation, although some did not relate their answer to the physical states of the reactants and products. Some candidates gave answers relating to the reaction being exothermic.
- (d) Most candidates gave the correct answer here.

Question 2

- (a) This question was found difficult by candidates. Many recognised that it would be monitored using the change in concentration of reactants but did not use the information given to explain how, for example change in colour.
- (b) (c) Many candidates were able to use the data to explain why the reaction is first order with respect to $\text{H}_2(\text{g})$ and $\text{ICl}(\text{g})$.
- (d) Most candidates answered this correctly.
- (e) Most candidates were able to calculate the rate constant.

- (f) This question was found challenging, and some candidates did not show understanding of using the rate equation to determine the rate determining step. Erroneous answers included ions and often equations showed three or four molecule collisions.
- (g) (i) This question was discriminating. Some very good explanations were seen. Most candidates described plotting a concentration-time graph and showing that half-lives are constant. However, many did not state that the initial rate could be determined by measuring the gradient of a tangent at the start of the reaction and subsequently using these results to plot a rate-concentration graph. A number of candidates did not address the question but rather discussed the practical method to generate results.
- (ii) This was found difficult by candidates. Common errors were 'so that all the H_2 is used up' and 'so that ICl is not the limiting factor'.
- (h) This was generally answered well, although some gave an incomplete answer such as it lowers the activation energy.

Question 3

- (a) Many candidates performed well here. Common errors were Cl_2 at the anode and H_2 at the cathode with dilute $CuCl_2$.
- (b) (i) This proved difficult for some candidates. The most common error was answering in terms of an electrochemical cell instead of electrolysis.
- (ii) This was generally well answered.
- (c) Many candidates gained full credit here. Common errors were 224 (division by 4 instead of 2) and 895 (no division by 2).

Question 4

- (a) (i) This was generally well known. Some candidates omitted state symbols for some or all substances.
- (ii) This was answered well by many candidates. A common error was stating a white precipitate would be formed.
- (b) Many fully correct answers were seen. Some candidates described the reaction becoming more endothermic down the group. This was not sufficient. A reference to enthalpy change of solution becoming more endothermic (or less exothermic) down the group was required.

Question 5

- (a) Most candidates answered this question well. The most common error was to form the ion by losing the 3d electrons before the 4s.
- (b) (i) This was usually well known; some candidates omitted 'atom' or 'ion' with metal in their answer.
- (ii) Many candidates answered this question well. Some gave incorrect stereochemical structures.
- (iii) This was well known. Some candidates stated that light energy is emitted or did not mention that d-orbitals are split.
- (iv) Many answered this correctly. A common error was stating that blue light is absorbed.
- (c) Most candidates gave the correct type of reaction and colour change.
- (d) (i)(ii) This was generally well answered. Common errors were MnO_4^- and Fe^{2+} .
- (iii) Many candidates were able to construct an ionic equation for Co^{2+} to Co^{3+} from the chosen oxidising agent in (i).

- (e) This was answered well. It is recommended that candidates use the form of three dimensional (3D) bonds shown in the syllabus – wedged and dashed bonds.

The drawing of an equatorial plane is not sufficient in the absence of 3D bonds. Common errors were drawing two cis- isomers or two trans- isomers, and optical isomerism.

Question 6

- (a) This was answered well by many candidates, most identifying KOH as one of the reagents. Common errors were KCl and K_2CO_3 , and H^+ as a product from reaction with K.

- (b)(i) Most candidates identified the $N=N$ bond here.

- (ii) This was answered well. Most candidates gave a two-step method (diazotisation following by coupling reaction). The most common errors were

- use of HNO_3 instead of HNO_2 in step 1
- omission of alkaline conditions in the coupling reaction (step 2)
- nitration of the 2-naphthol before reduction and diazotisation.

- (c)(i) This proved difficult for many candidates. Some candidates did not take note of the instruction and described the conditions for benzene only instead of phenol. Some stated that dilute HNO_2 would be used instead of dilute HNO_3 .

- (ii) This was usually well known.

- (iii) Many good answers were seen, however errors were frequently seen in the following areas:

- careless drawing of the curly arrow from the benzene ring to the N of the NO_2^+ which should start inside the ring system
- careless drawing of the partly delocalised ring which should not include the sp^3 carbon-2
- position of the positive charge on the intermediate which should be inside the partially delocalised ring system rather than on the sp^3 carbon-2
- careless drawing of the curly arrow as the C–H bond breaks which should start on or near the C–H bond, not on the hydrogen atom.

- (iv) Many correct answers were seen here.

Question 7

- (a) This question was generally well answered. A common error was giving the structural formula of asparagine.

- (b) Most candidates gained credit here. Common errors were carbonyl or ketone. The use of 'carboxylic' alone was not sufficient.

- (c) This question discriminated well. Common errors were

- omission of the label on the peptide bond
- inclusion of a trivalent carbon
- an incorrect linkage bond such as $-CO-NH-CO-$.

- (d)(i) Most candidates knew the definition in the syllabus and so received credit. Some did not give a precise definition, stating the pH would remain unchanged or stay constant.

- (ii) This proved difficult for many candidates. Often a singly charged amino acid/valine, or H_2O was used rather than H^+ or OH^- in the equations.

- (e) Many candidates gave two correct optical isomers with correct connectivity. The quality of the diagrams was generally good although some drew incorrect tetrahedral stereochemical structures.

- (f) Many candidates found this question challenging. Some did identify a correct organic hydrolysis product, although common errors were omitting H_2O as a reactant and giving an unbalanced equation.

Question 8

- (a) Most candidates gave the correct answer here.
- (b) This was generally well answered. The most common error was five chiral carbon atoms.
- (c) This question discriminated well.
- (d) (i) Many candidates found this question challenging. The most common responses were two and six.
- (ii) Most candidates predicted the range δ 190–220 although many also stated incorrectly δ 0–50. The correct number of peaks in each range was less commonly awarded.
- (iii) Many correct answers were seen. The most common error was two peaks.
- (iv) There were some good answers here. Candidates often identified the expected splitting pattern as a singlet, although some stated 'no splitting' which was insufficient. Many gave the correct explanation of no hydrogens on the adjacent carbons.
- (e) (i) Most candidates incorrectly identified $\text{HO}_2\text{CCO}_2\text{H}$ as the smallest product, however they gained partial credit for recognising this product was formed by oxidative cleavage/oxidation.
- (ii) Most candidates answered this correctly.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
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- Candidates should take care drawing three-dimensional tetrahedral and octahedral diagrams and use wedged and hashed bonds as appropriate.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

- (a) Most candidates were awarded full credit for this equation.
- (b) Many candidates were awarded at least partial credit here. Statements about strong bonding should have specified that it was *between oppositely charged ions*, or some equivalent statement.
- (c) (i) Many candidates did not appreciate that the question asks why the *solution* is alkaline, and instead they used the Brønsted-Lowry theory to explain why Na_2O is basic.
- (ii) This calculation was done well by many. A common error was to calculate 0.05 moles of Na_2O and then to calculate $[\text{OH}^-]$ to be $0.125 \text{ mol dm}^{-3}$.
- (d) This lattice energy calculation included the need to double the two data values for Na, and to halve the data value for the $\text{O}=\text{O}$ bond energy. Many candidates completed this difficult calculation successfully. Candidates should be reminded to show their working as this means that where an incorrect answer is given, it may be possible to award some credit for the method used.
- (e) The correct box was usually ticked, but a full explanation was seen much more rarely.

Question 2

- (a) Candidates' wording should be precise when definitions are asked for.
- (b) Candidates found this question difficult. Many candidates believed that a colour change would be involved or suggested that the amounts of reactants or products could be monitored. This would be extremely difficult to do in practice. However some candidates correctly realised that there would be a change in either total pressure or total volume, depending on the apparatus used.
- (c) Candidates generally received full credit for this question.
- (d) This question was usually fully credited.
- (e) This question was usually fully credited.
- (f) (i) This question was usually fully credited.
- (ii) Many answers were seen that were descriptions of a rate-determining step, such as 'this is the slow step', without actually explaining the reason for the answer in (f)(i). However a small number of excellent answers were seen, linking the $[\text{NO}]^2$ in the rate equation with N_2O_2 in step 2, clearly explaining this link, and including the involvement of one H_2 molecule in step 2.
- (g) (i) Candidates mostly knew the term half-life and gave precise definitions.
- (ii) Full credit was often awarded. Some candidates plotted a concentration of 0.0 mol dm^{-3} after four seconds.
- (h) (i) This discriminated well. Errors seen included equations involving N_2 or SO .
- (ii) Many inadequate answers were seen here, referring to the NO as 'not used up' or 'speeding up the reaction'. In this specific example the key observation is that the NO is involved in a chemical reaction, but it is subsequently regenerated.
- (iii) This was generally well answered.

Question 3

- (a) This was not well answered. The polarities of the anode and cathode were often misunderstood, and the ions discharged were often specified rather than the substances liberated.
- (b) (i) Many answers started with Ca and I_2 rather than Ca^{2+} and I^- .
- (ii) Candidates who had answered (b)(i) correctly usually answered this well, although some did not give reference to oxidation numbers.
- (iii) The production of a solid or liquid was often referred to, but mention of the evolution of a purple gas or vapour was much rarer. Candidates are not required to know the melting temperature of calcium iodide, but they should have deduced that an ionic solid such as this melts at a temperature well above the sublimation temperature of iodine.
- (c) There were many good answers to this question, using a wide variety of valid mathematical methods to reach the answer. No credit was given for Fe^{3+} unless supported by a correct calculation based on the data given in the question.

Question 4

- (a) The observations of heating calcium and barium in oxygen were not well known by many candidates.
- (b) Many candidates gained full credit here, although some did not refer to the decomposition temperatures, but instead made a statement about the stability of the compounds.
- (c) This discriminated well. Many good answers were seen in which the importance of the invisible nature of the gaseous product and the lack of colour change in the solid present were both appreciated and described.

Question 5

- (a) Most candidates answered this well.
- (b) Very rarely was full credit awarded here. The commonest error was in not appreciating that a linear complex must have the structure $Cl-Cu-Cl$; many square planar or tetrahedral complexes with composition $CuCl_4$ were seen. A significant number of candidates worked out the charge on the complex on the basis of Cu^{2+} not Cu^+ .
- (c) Most candidates correctly gave the name of the shape as octahedral, but a significant number missed the instruction to 'Label and state the value of one bond angle.'
- (d) There were many errors here, including:
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not starting reaction 2 with substance **A**, which should be $Cu(OH)_2$ or $Cu(OH)_2(H_2O)_4$
not specifying that the product **B** is a solution.
- (e) (i) Candidates often gave the correct answer here.
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- (iii) Credit was usually awarded for the statement ' $CuEDTA^{2-}$ is stable'; there were also a number of very specific and accurate answers that stated that ' $CuEDTA^{2-}$ is more stable than $[Cu(H_2O)_6]^{2+}$ '.
- (f) (i) A few candidates did not receive full credit but most had learned this definition.
- (ii) This was often answered well. Good answers showed correctly the formula and charge of the complex described, and explained that since ethanedioate is bidentate the zirconium ion has a co-ordination number of eight, whereas octahedral complexes have a co-ordination number of 6.

Question 6

- (a) (i) This was usually answered well. Common errors for **D** included 1-chloropropane and incorrect naming such as 'dimethyl chloromethane'.
- (ii) Many candidates gained credit, although a significant number gave 'Friedel-Crafts' without 'alkylation', and so credit could not be awarded.
- (b) (i) Many candidates gained credit here. It should be noted that answers including water, e.g. ' $C_2l_2(aq) + AlCl_3$ ' did not receive credit as $AlCl_3$ would be hydrolysed.
- (ii) This was well answered.
- (iii) Many candidates gave a correct answer.
- (iv) Many candidates drew two identical substances, one with the chlorine atom on the left hand methyl group and one with the chlorine atom on the right hand methyl group, perhaps not realising that

these represented the same molecule. Some candidates had difficulty showing their answers with correct skeletal formulae, and drew $C_6H_5CHClCH_3$. The answers expected were $C_6H_5CCl(CH_3)_2$ and $C_6H_5CH(CH_3)CH_2Cl$. However if the two optical isomers of $C_6H_5CH(CH_3)CH_2Cl$ had been drawn correctly, using three dimensional bonds, this was also credit-worthy.

- (c) The reduction reaction was better known than the oxidation reaction.
- (d) This was quite discriminating. Many good, accurate structures were drawn for the intermediate and curly arrows were often drawn correctly and accurately. Some candidates did not take advantage of the diagram of cumene on the left, with space next to it. It was hoped that this would be used to show the original attack, by a pair of electrons from the ring, towards the NO_2^+ ion.

Question 7

- (a) This was often answered well, although many unbalanced equations, and equations with H^+ as product, were seen.
- (b) (i) This discriminated well.
- (ii) This also discriminated well. For each substance a clear statement of either how and why the anion is stabilised or destabilised or how and why the O–H bond is strengthened or weakened was required.

In order for full credit to be awarded, the relative acidities of any two of the three substances had to be explained correctly. Many statements were seen that described resonance, or stated something such as 'the oxygen lone pair resonates round the benzene ring'. It was often difficult to award credit here due to lack of clarity of the description. Statements such as 'one lone pair on the oxygen atom is delocalised into the benzene ring' (for the phenoxide ion) or 'the negative charge is delocalised between the two oxygen atoms' (for the propanoate ion) are much clearer.

- (c) Credit could not be awarded for
tests that are based on acid strength alone
suggesting the iodoform test
naming a correct reagent without describing the observations that would be made.
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- (e) (i) Most candidates were awarded credit here.
- (ii) Many candidates chose to state that propan-1-ol has an absorption between 0.5 and 6.0 due to the OH proton, and propanal has an absorption between 9.3 and 10.5 due to the CHO proton, and so received full credit. Other correct answers, based for example on splitting patterns, were possible but more difficult and sometimes required careful wording.

Question 8

- (a) Candidates were generally able to identify the chiral carbon atom.
- (b) This question combined reduction with molecular formula calculation and proved to be difficult for most candidates.
- (c) (i) Candidates needed to recognise that the three C=C bonds will undergo oxidative cleavage, and then draw the skeletal formula of the correct molecule. Many found this difficult.
- (ii) and (iii) Candidates first had to deduce that initially the two smaller products are CH_3COCO_2H and HO_2CCO_2H . Then they had to remember that HO_2CCO_2H will be oxidised further to CO_2 .

Question 9

- (a) This discriminated well. Some candidates submitted formulae that were partly structural, which were not awarded credit.
- (b) Most candidates recognised the presence, and relevance, of a chiral carbon atom in noradrenaline.
- (c) (i) Many answers suggested that the reaction with phenylamine produces a stable diazonium ion due to delocalisation of lone pairs from the $-N_2^+$ group into the ring. However since this group is positively charged this would not help to stabilise it. Other answers were seen pointing out the ion is stable at 5°C , however it is stated that both reactions are performed at 5°C .
- (ii) N_2 as unreactive gas product was credited more often than the organic compound.

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Paper 9701/51
Planning, Analysis and Evaluation

Key messages

A few candidates need to be reminded of the importance of making sure that their answers are legible. Writing the answers in pencil and then going over in ink needs to be discouraged as this makes responses very difficult to decipher.

The understanding of significance of figures is important in science and it is necessary to consider data in relation to that. The requirement of three significant figures in **Question 1(e)** and in the table in **Question 2(c)** was usually achieved. The common error is to confuse significant figures with decimal places.

General comments

Most candidates attempted all of the questions.

Many candidates provided multiple responses to a simple question, which often leads to a contradiction within the answer. Thus **Question 2(g)** had 'State and explain' which clearly requires a statement of fact and an explanation to support the statement. In contrast **Question 1(i)** required one suggestion but was sometimes followed by an addition which could negate the original answer.

Candidates would benefit from performing or observing more chemistry practical techniques. Some indications of lack of practical experience were seen, such as in **Question 2(a)** where a thermostatically controlled water bath was also heated by a Bunsen burner.

Comments on specific questions

Question 1

- (a) A common error was to not show electrolysis apparatus rather an attempt at an electrochemical cell. Attempts here were a hybrid of electrolysis and electrochemical cell showing perhaps two identical half cells and batteries/power supplies in series. For those that had an electrolysis cell, common errors were missing batteries or power supplies or ammeters and named electrodes connected to an incorrect polarity. Usually the required labelling was well done.
- (b) The first part of this question about skin irritation was correctly answered by virtually all of the candidates although some included a lab coat even though the question precluded that. In the second part, many candidates appeared not to realise that disposal into a sink or drain is the first step in disposal to a large body of water and moved their answer on to a lake or sea; it is the initial sink/drain disposal that is to be avoided.
- (c) This was a straightforward question and candidates should be reminded to make sure they have read and understood questions. This question asked for measurements required to determine the electrode mass change. The answer of the mass of an electrode before and after electrolysis was common but there were many answers that were measuring time, current, etc. which have no relevance to mass change measurement. Part of the question 'include the appropriate unit' was missed by many of the candidates.
- (d) This was a simple calculation at which virtually all candidates succeeded.
- (e) This calculation was also usually well done, yet often the correct answer of 0.00444 (to three significant figures) was misreported as 0.004, 0.0044, or 0.00441.

- (f) There was more variation in this calculation, but most gained credit.
- (g) Candidates generally found this a difficult question to answer. The most direct answer of 'Two moles of electrons are produced in removing one mole of copper' was rarely seen. Many candidates gave electron capture by copper ions, presumably in the context of electrolysis depositing copper on the cathode. Answers such as 'copper requiring electrons' were often in the context of electron gain rather than flow.
- (h) This question was not well answered. Answers often started with a higher anode mass but did not link this to there being an apparent higher mass change leading to a lower estimate of the Faraday constant. Answers such as 'Faraday constant inaccurate' or 'it's because there are two electrodes' were seen.
- (i) Blackening could have been caused by copper(II) oxide or soot from the propanone and many candidates gave these as answers.
- (j) This question was not answered well which implies that candidates were not familiar with the practical features of such an electrolysis experiment. In this case it is the failure of all discharged copper(II) ions to adhere to the cathode as copper but instead to fall to the bottom of the beaker.

Question 2

- (a) This diagram question was well attempted by many candidates. Most candidates correctly provided a water bath and most candidates also gave the necessary thermometer. The heating of the water bath and maintaining its temperature at 30 °C caused the most difficulty. It is inappropriate to use a Bunsen burner as it lacks the fine control to maintain a moderate temperature. Thermostatically controlled heating was the best suggestion. A few answers featured a thermostatically controlled water bath being heated by a Bunsen burner.
- (b) (i) A popular misconception here was that the 200.0 cm³ value was a gas volume instead of a solution volume.
- (ii) Many, but not all, candidates identified the concentration of C₆H₅N₂⁺ as the independent variable and placed it on the x-axis. A substantial minority did not follow the instruction to add the maximum values to the axes at the points provided.
- (c) The table of data (to three significant figures) was generally done well. Some candidates did not maintain consistency in the number of significant figures they gave. Others gave the values to three decimal places (0.008) rather than three significant figures. There was occasional miscalculation, truncation and incorrect rounding.
- (d) Generally the plotting was done well. The data plots as a curve which may have been unexpected for many candidates since many drew a straight line.
- (e) Most tangents were drawn reasonably well, there being a range of slopes that were acceptable. Some candidates did not start their tangent at time zero, instead having one or more tangents along the curve or to the right of the curve. Most candidates with a reasonable tangent correctly gave the co-ordinates of two points in the correct x,y format. A few gave only one x and one y value. It is necessary to use co-ordinates spread over a substantial part of the tangent to produce a reasonable result. The usual criterion is to cover at least half of one of the axes. In this case the value of Δy had to be ≥ 0.0055 to satisfy this condition. A significant minority had co-ordinates too close together. The calculation of the gradient from the co-ordinates was usually correct but many had the unit incorrect. A number had mol dm³ s⁻¹ which was correct if the candidate had divided by 60 in the calculation, but many did not. A number used m to represent minute.
- (f) In order to determine half-life, the candidate must choose two concentrations where the second is half of the first following the obvious pattern of the first row. A minority of candidates did not do that. The time of each of the four concentrations was usually correctly read from the candidate's graph. Some candidates erroneously read the time from the tangent rather than the curve and others did not record the correct x-axis value. The calculation of half-life required a subtraction between the times. There were many candidates who did not do this.

- (g) Candidates needed to have obtained results in **2(f)** and use them to make a deduction here; most candidates correctly reasoned that the reaction is first order. This question and **Question 2(f)**, were the most commonly unanswered questions.

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Paper 9701/52
Planning, Analysis and Evaluation

Key messages

Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates did not recognise the techniques involved in **Question 2**, which was a question based upon a very common A Level practical.

Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures.

Candidates should be dissuaded from offering lists of answers beyond the number of responses asked for.

Candidates should be aware that lines of best fit need to split the plotted points in such a way as to have an approximately equal number of points (excluding anomalies) either side of the line. Drawing a line from the origin to the last point may not necessarily result in this outcome.

General comments

Question 1 involved an unfamiliar experiment but used techniques with which a typical A Level chemistry candidate should be familiar. Therefore, it is important that candidates read each sub-question carefully and apply their knowledge to the context of the experiment to fully appreciate what is required as an answer.

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

Also, in this question, candidates had to calculate their own co-ordinates for each point. Many candidates generated a plot which would not fit into the grid. Clearly, in this case, there has been an error in the generation of the co-ordinates and candidates are advised to check their working to find the error.

Comments on specific questions

Question 1

- (a) Nearly all candidates understood the need to wear gloves. Some extended this answer by adding a second precaution such as wearing a safety mask, which although not essential, did not contradict the original answer. Candidates are advised that if one precaution is asked for, only one should be given.
- (b) The colour of the Fe_2O_3 sol was given in the question as 'red' and this was the colour expected in the distilled water around the negative electrode (whilst the distilled water around the positive electrode remained colourless). In place of 'red' a significant number of candidates used 'brown', 'yellow' or 'green' which are the colours of precipitates of iron compound precipitates or solutions.
- (c) (i) Most candidates could successfully complete this calculation. Those who did not usually made an arithmetical slip or were out by a power of ten.

- (ii) Candidates generally made a good attempt at this description of preparing a standard solution, however, a significant number were unable to describe this. Common errors included use of non-distilled water, dissolving the solid in exactly 100 cm³ of distilled water before transferring to the volumetric flask, using a volumetric flask as the vessel to do the dissolving or using an incorrectly sized volumetric flask (usually 250 cm³).
- (d) Once again, the calculation provided little difficulty for most candidates. Occasionally errors in the power of ten were seen.
- (e) (i) This calculation was also generally found to be straightforward. However, a significant proportion of the candidates then went on to give the answer as simply 5 (cm³), ignoring the “exactly” in the question. Answers were expected to be 5.0 or even 5.00 (cm³).
- (ii) Most candidates gave a burette as the apparatus to measure accurately a small volume of solution. Graduated or 5 cm³ pipettes were also accepted, although measuring cylinders and beakers were not accepted.
- (f) Too many candidates focussed on the difference in accuracy between mass and volume measurements, often incorrectly, not realising that both methods involved both measurements. The real issue is that the smaller mass will lead to (much) larger percentage errors.
- (g) (i) Most candidates answered the question correctly. However some discussed the amount of precipitate formed or the rate at which it formed which was not credit-worthy.
- (ii) The majority of candidates used the tables and realised that the independent variable in Experiment 2 was the charge on the cation.
- (iii) Most candidates correctly identified the salt as $AlCl_3$, but few candidates went on to explain that this was because $AlCl_3$ contained the cation with the highest charge. Most candidates gave the loose response ‘Because it ($AlCl_3$) has the highest charge’ suggesting it was the salt, and not its cation that had the highest (positive) charge. Candidates must ensure clarity of wording in such explanations.

Question 2

- (a) Candidates needed to realise that as the solute lowered the vapour pressure, more heat/energy was needed to bring the vapour pressure up to atmospheric pressure. Some candidates had the right idea, but simply referred to a higher temperature being needed, which was a repeat of the information in the question. Many candidates tried, unsuccessfully, to explain in terms of the equation given in the stem.
- (b) Only just over half the candidates knew that cooling water should enter the lower aperture of a condenser, which might suggest unfamiliarity due to a lack of practical activity with this piece of apparatus.
- (c) Many candidates did not recognise that normal, glass thermometers can be read to the nearest 0.5 °C at best, once again suggesting unfamiliarity with apparatus.
- (d) This question was designed to make the candidates think carefully about the experimental procedure. Very few realised that the mass of water as the solvent had to be kept constant at 75.00 g and any hot gas escaping from the apparatus would reduce this mass. Many candidates ignored the statement ‘apart from for safety reasons’ in the question and answered in terms of safety.
- (e) Very few candidates realised that the pressure in the laboratory was below standard atmospheric pressure. Many candidates gave the imprecise response ‘The pressure in the laboratory was not at normal atmospheric pressure’ which did not receive credit as the lab pressure could have been different from normal atmospheric pressure by being greater. Some candidates opted for ‘heat loss’ or blamed it on the presence of anti-bumping granules, once again indicating a lack of familiarity with practical techniques.

- (f) (i) The calculation of the required figures was done well, but there were some who opted to round incorrectly or give their answers to an incorrect number of significant figures. Candidates do need to realise that if some calculated figures lead to points outside the grid then they should review their calculations.
- (ii) Many candidates did not plot the origin as one of the points but other than this, most scored credit for plotting. The line of best fit was completed less successfully. Candidates need to realise that a line of best fit should have approximately the same number of points on each side (ignoring anomalous points). Many opted simply to join the first point (the origin) and last point and consequently had more points above the line than below, which was not credited.
- (iii) Nearly all candidates identified the most anomalous point.
- (g) Candidates need to realise that when selecting co-ordinates from which to determine a gradient, these co-ordinates must have a significant distance between them; usually at least half of the line of best fit. Most could calculate the gradient with sufficient degree of accuracy and units were well worked out.
- (h) (i) A large majority of candidates said incorrectly that K_b would increase or stay the same. Sucrose has a higher molecular mass than glucose so there are fewer particles in the same mass. Thus, the value for ΔT measured by the candidate, and therefore the value of K_b calculated, will be less than the actual value.
- (ii) While most candidates said that tap water contained impurities, very few mentioned that they would affect the boiling point if they are **dissolved** in the water.
- (iii) There were many good suggestions, but few candidates picked up that 'twice' was emboldened in the question and there was a quantitative link, and that to double the reduction in boiling point, there must be double the number of particles, i.e. the two ions in sodium chloride.

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