CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Questions 2, **4**, **5**, **6**, **7**, **10**, **13**, **21**, **24**, **29**, **31**, **32** and **36** were answered well by the majority of candidates. Eight questions proved to be more challenging, with fewer candidates correctly answering **Questions 9**, **11**, **17**, **20**, **25**, **26**, **28** and **40**.

Comments on specific questions

Question 9

The most commonly chosen incorrect option was **C**. From the information in the question, each ethanedioic acid molecule loses two electrons when it is oxidised and each manganese atom gains five electrons when it is reduced. Therefore, five ethanedioic acid molecules are oxidised by two manganate(VII) ions. This means that one formula unit of potassium sulfate and two formula units of manganese(II) are produced. This requires three formula units of sulfuric acid in the reactants. Three formula units of sulfuric acid plus five molecules of ethanedioic acid contain a total of 16 hydrogen atoms, so eight water molecules are formed. Therefore, **B** is the correct answer.

Question 11

The most commonly chosen incorrect option was **C**. If we call the sulfur dioxide concentration ‘x’ and we insert what we know into the equilibrium expression, the expression is $6^2/(x^2 \bullet 0.5x) = 280$. Solving this gives, $x = 0.636\,\text{mol}\,\text{dm}^{-3}$, hence the correct answer is **D**.

Question 17

The most commonly chosen incorrect option was **B**. From the information in the question, the equation is:

$$6NaOH + 3Br_2 \rightarrow 5NaBr + NaBrO_3 + 3H_2O$$

30.2 g of $NaBrO_3$ is 0.20 moles; this amount reacts with 1.2 moles of NaOH, which has a mass of 48.0 g. Therefore, the correct answer is **D**.

Question 20

The most commonly chosen incorrect option was **C**. The ring in compound 1 has five hydrogen atoms on it, so a second methyl group could be introduced in five different positions. Compounds 1 and 2 each have two π bonds, each π bond has two π electrons, making four π electrons in total. Thus, the correct answer is option **D**.

Question 25

The most commonly chosen incorrect option was **B**. In order for this ring-forming reaction to work, the bromine atoms must be on carbon atoms 1 and 5 of an octane molecule. Carbon atoms 1 and 5 can then each be attacked nucleophilically by a lone pair from a nitrogen atom. Therefore, the correct answer is **D**.

Question 26

The most commonly chosen incorrect option was **B**. If the -OH group is removed along with a hydrogen atom from carbon atom 2, then two cis-trans isomers are formed. If the -OH group is removed along with a hydrogen atom from the methyl side-chain, then one alkene is formed. If the -OH group is removed along with a hydrogen atom from carbon atom 4, then two cis-trans isomers are formed. This gives a total of five different alkene products, meaning the correct answer is option **C**.

Question 28

The most commonly chosen incorrect option was **B**. Aldehydes are oxidised to carboxylic acids by mild oxidising agents, hence the correct answer is **A**.

Question 40

The most commonly chosen incorrect option was **A**. If X is ethanoic acid, two esters are possible; propyl ethanoate and methylethyl ethanoate. Therefore, X cannot be ethanoic acid meaning correct answer is option **C**.

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Paper 9701/12
Multiple Choice

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

General comments

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

Comments on specific questions

Question 2

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

Question 6

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

Question 10

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

Question 15

The most commonly chosen incorrect option was **C**.
With $MgSO_4(aq)$:

- $HCl(aq)$ will not give a precipitate.
- $NH_3(aq)$ will give a precipitate of $Mg(OH)_2$.
- $(NH_4)_2CO_3(aq)$ will give a precipitate of $MgCO_3$.
- $Ba(NO_3)_2(aq)$ will give a precipitate of $BaSO_4$.

The answer is therefore **D**.

Question 31

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

- since all molecules have $M_r = 34$, statement **1** is true
- since all molecules have $M_r = 34$, statement **2** is true
- since the equation is $H_2S + 3/2\ O_2 \rightarrow H_2O + SO_2$, statement **3** is true.

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

Question 39

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

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

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

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Paper 9701/13
Multiple Choice

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

General comments

Questions 7, **8**, **9**, **13**, **16**, **17**, **20**, **21**, **24**, **27**, **29**, **31** and **40** were answered well by the majority of candidates. Six questions proved to be more challenging with fewer candidates selecting correct responses for **Questions 2**, **11**, **26**, **28**, **33** and **39.**

Comments on specific questions

Question 2

The most commonly chosen incorrect option was **B**. However, answer **C** is correct because the data given is for an alloy and the calculation given in **C** includes only the values for copper. Option **B** also includes the contribution made to the alloy by gold.

Question 11

The most commonly chosen incorrect option was **C**. In order for 0.100 mol of magnesium carbonate to fully react, 0.100 mol of H_2SO_4, or 0.200 mol of HCl is required. Option **C** describes the use of 0.100 mol of HCl. Both option **B** and **D** describe the use of the correct amount of acid, however, since one molecule of H_2SO_4 can give rise to two H^+ ions, the proton concentration in **B** is higher than **D.** The graph shows a decrease in the rate of reaction for line Q compared to line P, confirming a lower H^+ ion concentration was used when the experiment was repeated. The correct answer is therefore **D**.

Question 26

The most commonly chosen incorrect option was **C**. Isomer **B** gives *cis*-hex-2-ene, *trans*-hex-2-ene, *cis*-hex-3-ene and *trans*-hex-3-ene. Isomer **C** only gives 2-ethylbut-1-ene, *cis* 3-methylpent-2-ene and *trans* 3-methylpent-2-ene. Option **B** is therefore the correct answer.

Question 28

The most commonly chosen incorrect option was **B**.
The question is effectively asking ‘how many structural isomers of $C_5H_{10}O$ have a carbonyl group?’ The seven isomers are:

pentanal
2-methylbutanal
3-methylbutanal
dimethylpropanal
pentan-2-one
pentan-3-one
methylbutanone.

Therefore, the correct answer is **C**.

Question 33

The most commonly chosen incorrect option was **D**. For most candidates this question depended on the validity of statement **2**. The enthalpy change of hydration of any specified gaseous ion is always negative, so statement **2** is therefore true and the correct answer is option **B**.

Question 39

The most commonly chosen incorrect option was **C**. For most candidates this question depended on the truth, or otherwise, of statement **1**. Carboxylic acids do give hydrogen gas when they react with sodium and they do not give a positive iodoform test. Statement **1** is therefore true; Z could be ethanoic acid. Hence the correct answer is option **A**.

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Paper 9701/21
AS Level Structured Questions

Key messages

Examiners were looking throughout this paper for careful, accurate answers that employed chemical terminology with precision. Candidates who were more concise tended to score better in extended answers, whereas overly long answers were often found to be contradictory.

Candidates are reminded that questions asking for explanations need not merely to state facts or rules of thumb, 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 and of the theory underpinning chemical behaviour.

General comments

Candidates are reminded that working in calculations should be shown to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

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. Papers should be cleaned of debris from erasers, as this too affects the legibility of responses. Centres are advised not to supply additional writing material, as candidates should be able to write all answers in the spaces provided.

Comments on specific questions

Question 1

Candidates who were clear and concise with their answers tended to score better in this question based on inorganic and physical chemistry. Examiners were able to award most marks to those answers that used precise terminology and drew explicit comparisons.

(a) (i) Examiners were looking for candidates to be specific with their answers, whereas many candidates did not explicitly reference the nucleus or outer electrons, and thereby did not score full marks.

(ii) Common mistakes seen were to give (aq) as the state symbol for H_2O and/or (s) for $Sr(OH)_2$, which was referenced as a solution. Some candidates gave an incorrect formula for the product: SrO, SrO_2 and SrOH were often seen.

(iii) Candidates are again reminded to be more specific with their answers: many stated that strontium produced the more alkaline solution (but failed to mention the production of strontium hydroxide). Candidates were often unclear about what was dissolving or causing the alkalinity.

(iv) Candidates are encouraged to avoid writing ‘gas given off’ or similar as an observation. Instead, observations of this nature can be more correctly expressed as effervescence.

(b) (i) Candidates’ answers were often ill focused and vague: when making comparisons, explicit naming of species is required; ‘it’ is not specific enough.

(ii) There were many varied answers to this question: amongst the common errors were XO_2 (wrong stoichiometry), and MgO and BaO (both white).

(iii) O_2 was often given incorrectly as a product of the decomposition.

Question 2

Most of this question focused on structure and bonding, and the physical properties of different species. As this tends to underpin much of the course, it was disappointing to note many candidates' vagueness in answering particular items.

(a) Many candidates chose to represent Mg_2Si as a covalent molecule, ignoring information given in the question. Only outer-shell electrons were necessary in the dot-and-cross diagrams, but correct charges were required.

(b) Most candidates scored at least one mark; many incorrectly gave $H_2O(aq)$, rather than $H_2O(l)$, as the reactant.

(c) There were some very good answers here.

(d) (i) Many candidates answered this well, though it was common to see entirely reversed dipoles, or the use of full rather than partial charges.

(ii) This item was vaguely answered by many: it was necessary to link the shape with the idea of individual (bond) dipoles cancelling each other.

(e) Very few candidates mentioned (high) activation energy, focusing solely on the differing bond energies of Si—H and C—H and not accounting for the need to break all bonds in this instance.

(f) (i) Many candidates identified water as a product, but most struggled to identify sodium silicate, Na_2SiO_3, correctly: a wrong formula was a common error.

(ii) Many candidates appeared to misinterpret the question, giving answers about the vigour of the reaction. Unfortunately, Examiners were unable to give credit for answers that labelled SiO_2 as acidic but then qualified it incorrectly as a Brønsted–Lowry acid.

Question 3

A challenging question, this was nevertheless answered well by candidates who worked methodically and showed due care both to mathematical accuracy and the precision of terminology employed. A surprising number of candidates showed a lack of familiarity with the ideal gas model and $pV = nRT$, and with the concept of the mole.

(a) Very many different attempts were seen to this question. Candidates are reminded that such equations **require** state symbols, (g) for the atomic species.

(b) Most candidates were able to score at least one mark for this item.

(c) Many candidates answered this item well.

(d) (i) Candidates are reminded not to round their working until the final presentation of their answers: many inaccuracies are produced otherwise. Most errors in calculations otherwise orginated from erroneous conversions of quantities to SI units, and the use of $M_r(Cl_2) = 35.5$ rather than 71.0.

(ii) Many candidates again failed to recognise that chlorine, Cl_2, is diatomic. Some candidates did not use Avogadro's number at all.

(iii) There were some good answers to this question, but it was the most poorly answered of the paper. Examiners were looking for candidates to explain why the ideal gas model breaks down under certain conditions, and therefore to recognise how real conditions become significant rather than negligible.

Question 4

This organic chemistry question looked to test mainly candidates' competency with AO1 tasks. Many items were answered well, though candidates are advised to make note of the number of marks available for each item: **4(d)(ii)**, for example, attracted 8 marks, yet many answers failed to include enough material in response.

(a) Many candidates neglected to identify the position of the alkene group in their answer.

(b) This item was answered well.

(c) (i) A significant number of candidates appeared unfamiliar with the idea of a molecular formula.

(ii) This item was answered well.

(iii) This item was answered well.

(d) (i) Candidates are reminded that carbonyl and carboxyl groups are different: the carbon atoms have different oxidation states and behave differently. D contains a carboxyl group.

(ii) Many candidates were able to secure the majority of marks, with good observational notes recorded despite incomplete or incorrect identification of the molecules.

Question 5

This question looked to test candidates' understanding of key organic chemistry concepts: chemical and physical properties were assessed, as were a couple of definitions. Candidates are reminded of they need to present structures carefully and unambiguously.

(a) Examiners did not see many correct answers to this item: the most common omissions were to reference an electron-**pair** donor and the negative charge on the cyanide ion.

(b) (i) This item was answered well.

(ii) There were many good answers to this question, but some candidates drew questionable 3D structures and showed incorrect connectivity.

(c) Many candidates failed to hydrolyse the nitrile group; others misinterpreted the question.

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Paper 9701/22
AS Level Structured Questions

Key messages

When asked to give specific expressions, e.g. concentrations or partial pressures, standard abbreviations are required.

Use of non-standard abbreviations in explanations e.g. VWFA, should be discouraged unless there is a statement that explains what is meant by the abbreviation used.

All equations described should be balanced.

General comments

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

Comments on specific questions

Question 1

(a) **(i)** Clear explanations why methylpropane and butane are a pair of isomers were produced by the majority. Occasionally the incorrect molecular formula of these molecules was described.

(ii) Correct descriptions of the type of isomerism shown as either structural or chain, were common. There was confusion in some responses, which described the pair of molecules as an incorrect type of structural isomer e.g. position isomers. A very small number of responses incorrectly referred to the isomers as geometric.

(b) Good responses related the information provided in the question to le Chatelier's principle and went on to state and explain the effect on the composition of the equilibrium mixture in terms of the exothermic nature of the forward reaction. Weaker answers made no reference to the composition of the mixture.

(c) **(i)** Many responses applied knowledge and understanding of the term *dynamic equilibrium* to the graph to show the time at the point when there was no longer a change to the gradient of both curves. A common incorrect answer indicated the time when the concentrations become equal.

(ii) Most candidates correctly described the amount of methylpropane and butane in the mixture at equilibrium. Incorrect identification of the curves representing the two isomers was the most common mistake.

(iii) The expression for K_c for this reaction should include the term K_c and the concentrations of the two isomers should be represented using square brackets.

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

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

Question 2

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

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

(b) **(i)** Despite the question stating that the reaction took place between hydrogen and chlorine at room temperature, some answers stated 'high temperature' was required as the specific condition.

(ii) Good responses produced a balanced equation representing the reaction with appropriate state symbols and use of $\rightleftharpoons$ to represent the reversible reaction. Identification of iodine as a liquid or hydrogen iodide as a solid, liquid or aqueous were common mistakes. Some equations erroneously showed the reaction of the atoms of hydrogen and iodine.

(c) **(i)** The definition of a Brønsted-Lowry acid was well known.

(ii) Correct identification of the acid reactant HCl was seen frequently. However, there was confusion with the term *conjugate base*, many responses describing H_3O^+ as the conjugate base of HCl.

(iii) A significant proportion of answers identified the bond formed between the hydrogen cation and water as a dative covalent bond or co-ordinate bond. Some incorrectly stated that the bond formed was a hydrogen bond.

(iv) This question proved challenging for many. Excellent responses appreciated that the H_3O^+ ion contains three bond pairs and one lone pair of electrons and correctly deduced the shape and H-O-H bond angle in the H_3O^+.

Question 3

(a) **(i)** The equation for the reaction of silicon tetrachloride, including state symbols, presented numerous difficulties. Many candidates stated the correct formulae for reactants and products but failed to correctly balance the equation. State symbols were omitted by some, and where used, the correct state of silicon tetrachloride was rarely seen.

(ii) A relatively small number of responses correctly described the reaction of silicon tetrachloride with water as a hydrolysis reaction. Hydration, redox and neutralisation reactions were common incorrect responses. Reference to an exothermic reaction was described by some, even though the question stated 'Ignore the endothermic/exothermic nature of the reaction'.

(iii) Correct bonding of the two compounds was seen frequently. Reference to intermolecular forces present in sodium chloride or giant covalent structure of silicon tetrachloride were seen in weaker responses.

(iv) This proved challenging for many. Excellent responses were seen by those who explained the difference in bonding in terms of the difference in electronegativity between the atoms of sodium and chlorine in $NaCl$ and silicon and chlorine in $SiCl_4$, resulting in complete transfer of electrons or shared pairs of electrons.

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

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

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

(b) (i) The correct identification of the oxidation number of chlorine was described in the majority of answers.

(ii) Many responses correctly identified the type of reaction occurring as disproportionation; a relatively small number of answers spelled the term correctly.

(iii) The majority of answers appreciated that the chlorine is added to water to kill micro-organisms. Some excellent responses gave details of how the micro-organisms were killed in terms of the active species involved.

(c) Many equations correctly identified $\mathrm{NaC}l\mathrm{O}$ as one of the products of the reaction. A significant number of responses combined the reaction of NaOH with $\mathrm{HC}l$ and $\mathrm{HC}l\mathrm{O}$. Often equations were not correctly balanced.

Question 4

(a) The use of crude oil as a source of hydrocarbons was commonly seen. However, there were incorrect references to fruits as the source. Detailed descriptions of the fractional distillation process were seen in good answers; others simply stated the name of the process.

(b) (i) The correct identification of the process was common.

(ii) Representation of the formulae of hexane, butane and ethene were well known and many equations showed these correctly as the products in the equation. Not all equations were balanced.

(c) The correct calculation of the volume of carbon dioxide produced was commonly seen. Occasionally, answers calculated the molecular mass of ethene incorrectly or did not use the correct stoichiometry. Some candidates did not use the idea that 1 mole of gas occupied 24.0 dm^3 volume at room temperature and pressure and used the ideal gas equation instead.

(d) (i) The meaning of the term *free radical* as a species containing an unpaired electron was rarely seen. Frequent misconceptions included ‘containing a single electron’, ‘free electrons’, ‘a lone pair of electrons’ or ‘it is an unpaired electron’.

(ii) Correct identification of the type of bond breaking was common but was not always spelled correctly. A smaller number of responses clearly explained the process in terms of each of the products keeping one of the bonded pair of electrons.

(iii) Correct identification of the stage of the reaction mechanism was common; correct spelling of the term *propagation* was rare. Incorrect answers included identification as initiation, termination, step 3, or as free radical substitution.

(iv) For many, this equation proved straightforward. Incorrect responses included products of hydrogen free radicals and chloromethane or the production of positively charged ions.

(v) This question proved challenging. Some excellent answers described the presence of sigma and pi-bonds in alkenes compared to only sigma bonds in alkanes and described the pi-bond as key to the reaction of alkenes with electrophiles. Some referred to the C=C of alkenes as the pi-bond rather than a sigma bond and a pi-bond. Many responses were not specific to sigma and pi-bonds, with explanations given in terms of the region of high electron density in C=C.

Question 5

(a) (i) Naming ester **V** presented difficulties for many. Ethyl propanoate and propyl methanoate were common incorrect answers.

(ii) Identification of an alkali, like aqueous NaOH, to form the salt of the carboxylic acid and alcohol was not well known. Addition of aqueous $\mathrm{HC}l$ was a common incorrect response.

(iii) In a small number of answers, an incorrect alcohol was identified as the product. Many answers realised that propan-1-ol is produced but did not show the full displayed formulae; omission of the O-H bond was common. Occasionally, skeletal formulae was incorrectly used to draw the structure.

(iv) Many uses for ester **V** were seen. Solvents and perfumes were the most common responses.

(b) **(i)** The majority of responses worked out the correct empirical formula of **W** using the % composition of the elements present. Common mistakes involved finding the smallest whole number ratio of the % values with no use of relative atomic mass, calculating relative atomic mass/percentage mass in the first step of the reaction and incorrect rounding of values to find the whole number ratios.

(ii) Good responses stated that the molecular mass of **W** is required to find its molecular formula.

(c) **(i)** Interpretation of the skeletal formula of the compounds to deduce the common molecular formula was generally well done. Some answers reflected difficulties interpreting the skeletal formulae and gave incorrect numbers of carbon and hydrogen atoms.

There was occasional misunderstanding of the term *molecular formula*, either showing three different structural formulae or descriptions of the different functional groups present.

(ii) Many appreciated that **X** and **Z** contained the same functional group, therefore the observation in **X** was mirrored with that of **Z**. A relatively common misconception was that esters react with sodium. When the carboxylic acid, **Y**, was added to sodium, effervescence was often described but the formation of a precipitate was a common incorrect response.

(d) This equation proved demanding. Many attempts showed carbon dioxide and water as products of the reaction. The formula for sodium carbonate was not well known and was seen frequently as $NaCO_3$. Many answers described the reaction of ethanoic acid rather than methanoic acid. Even when the correct species were described in the equation it was not always balanced.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions

Key messages

Candidates are reminded to read questions carefully and follow the instructions that are given in the question stem. If a question asks for two observations, only two observations should be supplied. Over answering of questions increases the risk of introducing contradictory statements in candidates' responses.

General comments

Candidates should be fully aware of the definition of dative/coordinate covalent bonds, in order to understand how 'dative covalent bonds' are used in all branches of chemistry.

There were weaknesses in certain areas of organic chemistry, notably the naming of organic compounds, the formulae of organic reagents and the definition of a nucleophile**.**

Candidates would benefit from practising the skills needed to 'describe and explain' a chemical reaction.

Comments on specific questions

Question 1

(a) (i) Many candidates recognised that whilst all three atoms, ^{40}Ar, ^{40}K and ^{40}Ca, have the same atomic mass/mass number, the subatomic particles which the three atoms have in common is the total number of protons and neutrons or same 'nucleon number'.

(ii) Many candidates appreciated that the individual atoms each have differing numbers of protons, neutrons and electrons.

(b) Many candidates who were aware that the sum of the percentage abundance of the two isotopes of sulfur, ^{32}S and ^{34}S, added up to 100%, correctly answered this question using either (x) and (1 – x) for the individual abundances.

(c) (i) In a sulfur atom, the orbital with the lowest energy is the one closest to the atomic centre, *i.e.* the 1s orbital. Many answers identified the $3p^4$ as the orbital of sulfur having the lowest energy, possibly confusing this with the concept of ionization energy.

(ii) The dumb-bell shape of a p orbital was generally well known. A number of sketches contained lobes of distinctly different sizes, and shape, possibly confusing the p orbital with a hybrid orbital.

(iii) The loss of the first electron from sulfur was generally acknowledged to be from the 3p sub-shell; the explanations for which of the four electrons was being removed were less clear. Several answers stated that it was the outer shell electron, but did not specify that this electron was the furthest away from the nucleus.

(d) (i) Many candidates incorrectly included a pair of electrons in a 3p orbital when giving the electron configuration of the third shell of a phosphorus atom.

(ii) This question required an understanding that repulsion between a pair of electrons, in a 3p orbital, was responsible for the lower first ionisation energy of S, compared to that of P. The electron pair repulsion was often correctly identified as the reason for the lower first ionisation energy; the location of the actual pair of electrons in a 3p orbital was poorly described.

Question 2

(a) (i) The description of the regular arrangement of iodine molecules, within the solid, was rarely seen as an answer.

(ii) The forces of attraction present in solid iodine molecules are covalent bonds between the I atoms and specifically, 'temporary induced dipole – induced dipole attractions' between the I_2 molecules. The forces of attraction overcome when solid iodine molecules are heated are only the intermolecular forces of attraction; 'temporary induced dipole-induced dipoles'. Candidates regularly did not understand that the 'covalent bonds' are the result of the forces of attraction between the iodine atoms, in a molecule, and frequently an incorrect intermolecular force of attraction was mentioned.

(b) (i) and **(ii)**

A high proportion of candidates did not demonstrate secure understanding of 'dative covalent/coordinate' bonds and how they form.

Consequently the number 8 frequently featured, for an answer to **(b)(i)**, as the number of co-ordinate bonds present in Al_2I_6.

The three valence electrons in each aluminium atom form three covalent bonds with three iodine atoms, in which each atom contributes a single electron. Each aluminum then has six electrons in its outer shell. Two iodine atoms then each contribute a further pair of electrons to the aluminium's outer shell to form two dative covalent/co-ordinate bonds.

(c) (i) Writing balanced equations, using oxidation numbers, caused problems due to candidates incorrectly transcribing the formulae of species given in the stem of the question. Hydrogen sulfide appeared to cause most problems with H_2SO_3 regularly being incorrectly quoted as its formula.

Many full-credit answers were seen.

(ii) Answers using equations containing the correct species often gained marks here for recognising that I underwent oxidation when its oxidation number changed from –1, in HI, to 0, in I_2.

Many candidates incorrectly described the change in oxidation numbers of S. The oxidation number of sulfer changes from 6, in H_2SO_4, to 0 and –2, in S and H_2S respectively.

Question 3

(a) Generally, this question was quite well answered with many candidates stating that a 'white' light was observed leaving a 'white/grey' ash as a residue.

(b) (i) There were many correct answers for the reaction between MgO(s) and HCl(aq).

(ii) Several full-credit answers of 'neutralisation' were seen. The most common incorrect name for this type of reaction was 'double replacement'.

(c) Correct answers often included statements referring to either strong 'ionic' or strong 'covalent' bonds, both of which required high energy to break down.

The 'giant' nature of either an ionic or covalent structure was not regularly recognised.

(d) (i) A number of incorrect formulae for magnesium carbonate was seen, notably $Mg(CO_3)_2$. State symbols were often omitted and frequently, O_2 appeared as a product.

(ii) The type of reaction for the formation of MgO when $MgCO_3$ underwent thermal decomposition was often described as 'combustion', which would require the presence of oxygen as a reactant.

Question 4

(a) Candidates who were aware that fossil fuels contain sulfur compounds as impurities were then able to offer creditable arguments for the presence of SO_2 in the atmosphere during the combustion of the fossil fuels.

(b) (i) The 1:1 ratio for the use of SO_2 to form H_2SO_4 was a straightforward moles calculation converting the SO_2 into moles and then into a mass of H_2SO_4.

(ii) The presence of N_2 in the air/atmosphere was frequently absent from many answers and its part in forming NO_2 was not well understood by a significant number of candidates.

(iii) It was generally acknowledged that 'lightning' or 'thunderstorms' provide the conditions to bring about the formation of NO_2, in the atmosphere, from a natural cause.

(iv) A high number of candidates were not aware that the prime function of a catalyst is to 'increase the rate' of a reaction.

Statements mentioning that NO_2 is not 'used up' were frequent, but there was little detail or evidence supporting this comment, for example, 'it is regenerated by the reaction of NO with O_2 in the air'.

Question 5

(a) (i) In many answers, there was some confusion about when to use 'nitrile' or 'cyanide' in the naming of pentanenitrile/1-cyanobutane, $CH_3(CH_2)_3CN$.

Common incorrect answers included 1-nitrilebutane and 1-cyanopentane

(ii) A nucleophile, actually donates a pair of electrons to form a (dative) covalent bond. Many answers fell short of a correct definition, often stating that the lone pair of electrons was 'attracted' to electron deficient areas.

(iii) The cyanide ion requires a negative charge to act as the nucleophile.

Potassium cyanide or just 'cyanide' was frequently mentioned as 'nucleophiles' in this reaction, which are both an inaccurate identifications of the reacting species in this reaction.

(iv) Candidates' answers often included vague statements referring to 'one functional group being replaced by another' but not identifying the actual species involved in this substitution reaction

(b) The conversion of a halogenoalkane to an amine requires the use of ammonia; the reaction also requires 'heating', either in a sealed tube or under pressure.

Aqueous ammonia is not the recommended reagent – the solvent is usually ethanol.
The conditions for this reaction were rarely correct in this question.

(c) (i) The correct link between the decreasing time for hydrolysis of a halogenoalkane and the identity of the halogen, X, in the C-X bond was often present. Many answers contained statements that $(CH_3)_3CI$ required the least amount of energy to break the C-I bond, but did not mention the energy required to break the remaining C-Br and C-Cl bonds.

Candidates' answers mentioning the increasing reactivity of the halogenoalkanes, containing the C-Cl, C-Br and C-I bonds, associated with the decreasing strength of the C-X bond gained credit.

(ii) Many responses developed an argument for an S_N1 mechanism but were a little disjointed in their explanation. Frequently, answers stated that the tertiary halogenoalkanes were stable, rather than the actual tertiary carbocation intermediate.

(iii) Primary halogenaolkanes undergo S_N2 reactions with aqueous silver nitrate; many candidates gave either correct formulae or correct names.

Question 6

(a) (i) The observations when aqueous bromine is added to alkenes were generally well answered.

(ii) A number of the structures for **X**, **Y** and **Z** contained oxygen. Some candidates did not recognise that the reagent of hot, concentrated, acidified manganate(VII) ions cleaves a carbon-carbon double bond to form carbonyl compounds and CO_2, dependent upon the structure of the alkene.

(iii) The molecular formula of the hydrocarbon, C_4H_8, was often correct.

(b) (i) **V**, $CH_3(CH_2)_2CH_2OH$, was generally recognised as a primary alcohol. Frequently **W**, $(CH_3)_3COH$, was mistaken for an aldehyde group, instead of a tertiary alcohol.

(ii) The reaction of alcohols with sodium produces hydrogen gas and a sodium alkoxide. Common errors included H^+ as a product and equations where the OH group of the alcohol was replaced by an Na atom.

(iii) A different number of reagents can be used to distinguish between a primary and tertiary alcohol. The majority of candidates chose a reagent containing acidified dichromate(VI) ions and correctly stated the observations for its use with these alcohols.

If formulae are used to name a reagent then they need to be correct – frequently, the dichromate(VI) ion was given as Cr_2O_7 or CrO_7^{2-}.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

Candidates should be reminded to read the full method before starting an experiment so that they record all the required data.

Candidates should ensure their data reflects the precision of the apparatus used.

Candidates should ensure that all headings in results tables and descriptions of observations are precise.

It is essential that candidates enter the information regarding session and laboratory on the front cover of the paper so that results can be matched with the supervisor values that are relevant to that session/lab.

General comments

Candidates need to take time to study the instructions more closely both in terms of the practical method and in terms of further information provided in the questions. Examples of where pertinent instructions were missed were where candidates did not record the mass and/or volume required in **1(a)** or did not record all the required mass readings in **2(a**).

Most centres correctly included the supervisor script(s) and report(s) but it is a matter of concern that some centres only sent one supervisor's script purportedly covering multiple sessions and laboratories. In this case it is essential that the concentration of solutions issued is the same for all candidates.

Comments on specific questions

Question 1

Responses were rather centre-dependent indicating that some candidates had had more exposure to this type of experiment than others. This is in spite of the fact that this is one of the practicals specified in the syllabus.

(a) A number of candidates did not record the mass of solid and/or the volume of gas in the space specified. Most candidates scored some accuracy marks but it appeared, by the low volume of gas collected, that some had allowed much of the carbon dioxide formed to escape.

(b) (i) Most candidates gained the mark for calculating the number of moles of carbon dioxide collected.

(ii) and **(iii)** While most candidates carried out the calculation correctly, some did not subtract the 60 and others did not choose the identity of **M** to correspond with the A_r calculated.

(c) (i) Few correct responses were seen. Acceptable answers considered that too much gas to fit in the measuring cylinder would be produced or that the acid would no longer be in excess. Most candidates merely considered possible percentage inaccuracy. This is clearly a negligible effect in the context of the question.

(ii) Many candidates correctly discussed the solubility of carbon dioxide in water.

Question 2

It was apparent, by the small loss in mass recorded by some candidates, that they had not heated the solid to a sufficiently high temperature to ensure complete decomposition. Heating methods, such as spirit burners that do not allow high temperatures to be reached, are unsuitable. If a fixed gas supply is not available, portable gas burners are perfectly acceptable.

(a) Candidates must ensure that they record all the data requested, that they quote all values to an appropriate number of significant figures and that the headings in any table are correct and include the relevant units.

Common errors included:

'weight' instead of 'mass'
incorrectly calculated data – often confusing the mass of residue and the mass of carbon dioxide lost
missing/incorrect units
imprecise headings – often giving the mass of residue as being mass of **FA 3** when, after heating, the solid is no longer **FA 3**.

Most candidates gained at least 1 mark for carrying out the practical accurately.

(b) (i) Most candidates also calculated the number of moles of carbon dioxide.

(ii) Since the question specified that the mass of **FA 3** should be used to calculate the A_r, for full marks, this, rather than the mass of oxide had to be in the calculation. Many candidates carried out the calculation successfully.

(c) Acceptable answers had to be precise in referring to what was absorbed. Many incorrect answers suggested that the lid was to prevent the loss of either solid or gas.

(d) (i) Many candidates correctly recognised the need to heat to constant mass but a minority suggested merely heating for longer or heating to a higher temperature.

(ii) Many candidates were unable to adequately answer this item. It was necessary to add an acid and also to note the effervescence/carbon dioxide formation.

(e) (i) Whilst many candidates stated that less carbon dioxide would be formed, few went on to relate this to the number of moles and hence the effect on the A_r of **Q**.

(ii) Many candidates correctly recognised the validity of the suggestion because of the mole ratio.

Question 3

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

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

Candidates should also be reminded that descriptions of observations must be precise – 'yellow', for example, is not the same as 'cream', and whether a solution or a precipitate is formed should be stated.

(a) (i) All candidates gained some marks although many were lost through imprecise descriptions, as highlighted above.

(ii) and **(iii)** Few candidates gave a correct ion present in **FA 4** or **FA 5**. Of those few candidates that suggested **FA 4** was an iodide, even fewer went on to identify the iodine formed. Even though it had already been used to show the presence of iodide ions, the most popular suggestion for a reagent to test for the coloured product was aqueous silver nitrate.

(b) **(i)** Most candidates stated that the solution turned litmus blue with only a few saying, incorrectly, that it was a gas that gave this change.

(ii) Only a minority of candidates gained this mark and many candidates left the line blank or suggested products in addition to **Q**(OH)$_2$.

(c) **(i)** This part was also not answered well. A number of candidates suggested water and, perhaps more surprisingly, a number suggested organic solvents.

(ii) Aqueous ammonia is actually the only reagent that is needed to confirm the identity of **M** and **Q** and most candidates suggested that it should be used.

(iii) Only a minority of candidates actually answered the question and stated whether or not their results in **(ii)** confirmed or disagreed with their conclusions in **Question 1** and **Question 2**. The actual answer could be yes or no, and either was accepted if it followed the evidence.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should ensure that all headings in results tables and descriptions of observations are precise.
- It is essential that candidates enter the information regarding session and laboratory on the front cover of the paper so that results can be matched with the supervisor values that are relevant to that session/lab.

General comments

Candidates need to take time to study the instructions more closely both in terms of the practical method and in terms of further information provided in the questions. Examples of were instructions were not adhered to were seen in **1(a)**, where candidates did not record burette readings for the rough titre and in **2(a)**, where candidates did not record all the mass readings. Nevertheless, the paper generated a wide spread of marks with some excellent responses seen.

Most centres correctly included the supervisor script(s) and report(s) but it is a matter of concern that some centres only sent one supervisor's script purportedly covering multiple sessions and laboratories. In this case it is essential that the concentration of solutions issued is the same for all candidates.

Comments on specific questions

Question 1

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

(a) Most candidates gained most, if not all, of the marks in this section. However, some common errors were evident:

- using a mass of solid outside the range specified
- burette readings not recorded for the rough titre
- burette readings recorded to 1 dp for the accurate titres
- performing further accurate titrations when two titres were within 0.10 cm^3.

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

Almost all candidates gained at least one mark for accuracy.

(b) Most candidates gained the mark for the mean with very few rounding errors seen.

(c) (i) Most candidates gave their answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the expected 3 or 4 significant figures but a number did not realise that x must be an integer in **(v)**.

(ii) Many excellent answers were seen with only a very small number mistakenly using a volume other than that which they had calculated in **(b)** or omitting the use of 1000.

(iii) Most candidates used the 1:1 mole ratio indicated by the equation but very few gained the mark since, in most cases, the formula of the salt was incorrect and/or the state symbols were omitted or incorrect.

(iv) Many candidates obtained answers that were incorrect by a factor of 10. This arose because of the 250 cm^3 of solution prepared only 25.0 had been used in the titration. Candidates might have realised that they had made an error when the value of the M_r they obtained, and hence the value of x, was so large.

(v) The mark for calculating the value of x was awarded, even if it was unlikely, if it correctly followed the M_r in **(iv)**. The most common error was not using A_r values correct to one decimal place. This is the accuracy to which they are quoted in the Periodic Table provided and this is therefore the accuracy expected for AS or A level use.

(d) Correct answers to this section were rare. Many candidates apparently thought that they had been provided with solid barium amidosulfonate and described an experiment designed to try to dissolve the solid. Others realised that they had to mix reagents containing barium (in some form) with amidosulfonate ions but very few realised that they should use aqueous solutions containing the relevant ions as if they were using a precipitation method to prepare an insoluble salt. Extremely few candidates appeared to have carried out any practical to conclude that the salt is indeed soluble in water.

Question 2

It was apparent, by the small loss in mass recorded by some candidates, that they had not heated the solid to a sufficiently high temperature to ensure complete decomposition. Heating methods, such as spirit burners that do not allow high temperatures to be reached, are unsuitable. If a fixed gas supply is not available, portable gas burners are perfectly acceptable.

(a) Candidates must ensure that they record all the data requested, that they quote all values to an appropriate number of significant figures and that the headings in any table are correct and include the relevant units.

Common errors included:

‘weight’ instead of ‘mass’
incorrectly calculated data – confusing the mass of residue and the mass of carbon dioxide and water lost
missing/incorrect units
imprecise headings – often giving the mass of residue as being mass of **FB 4** when, after heating, the solid is no longer **FB 4**
calling the final product a precipitate.

Most candidates gained at least 1 mark for carrying out the practical accurately.

(b) (i) Most candidates also calculated the number of moles of copper(II) oxide and gave an answer to an acceptable number of significant figures (2–4).

(ii) Most also correctly calculated the M_r of $CuCO_3.Cu(OH)_2$ although a minority did not divide their answer to **(b)(i)** by 2.

(iii) The use of the Periodic Table to calculate the M_r was achieved by nearly all candidates. Many also correctly determined a value for *y* but very few candidates satisfactorily answered the question by commenting on the value obtained. Most merely restated the calculated value, which is not acceptable as a comment.

(c) Many candidates correctly recognised the need to heat to constant mass but a minority suggested heating for longer/more times or heating to a higher temperature.

Question 3

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

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

Candidates should also be reminded that descriptions of observations must be precise – ‘brown’, for example, is not the same as ‘off-white/beige/pale brown’ and whether a solution or a precipitate is formed should be stated.

(a) (i) Nearly all candidates scored some marks, but few made sufficient observations to score all the 3 marks available. Candidates should be encouraged to record as many observations as possible.

(ii) Most candidates noted the fizzing but far fewer actually tested for the carbon dioxide produced. When vigorous effervescence occurs with a dilute acid it can, at this level, only really show the presence of a carbonate or a metal.

(iii) Many candidates gained the mark for the correct formula.

(b) (i) All candidates gained some marks, but many were not awarded when the description of the observation was too imprecise. The use of the Qualitative Analysis Notes can help e.g. the description of the precipitate formed from $Mn^{2+}(aq)$ and $OH^{-}(aq)$.

(ii) Many candidates clearly recognised the formation of $Mn(OH)_2$ but the mark was not awarded if they stated that **FB 6** was sodium hydroxide. The nature of the cation cannot be deduced from the information available.

(iii) Many candidates gave a correct ionic equation.

(iv) Correct answers were only seen from very high scoring candidates, with very few candidate realising that $Cu(OH)_2$ would react with hydrochloric acid but $BaSO_4$ would not.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

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

General comments

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

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

Comments on specific questions

Question 1

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

(a) I Almost all candidates gained the mark for drawing a suitable table for their results. Some candidates split their tables between pages 3 and 4 which occasionally led to omissions in the data required. When 'a table' is specified it should normally involve no repeat of headings.

II This was well answered. The most frequent error was to omit, or give an incorrect unit for, rate.

III This mark was more commonly lost. Candidates were using burettes to measure the volumes of **FA 1** and water so should have recorded these to .00 (or to .05 if they overshot when delivering a volume). Many ignored the instruction to record the time taken as an integer and others should be reminded that, for example, 33.0 is not an integer.

IV and **V** were gained by most candidates with the selection of either 25.00, 30.00 and 35.00 cm^3 or 30.00, 35.00 and 40.00 cm^3 of **FA 1** being common.

VI Most candidates gained the accuracy mark for the correct trend of times with volumes of **FA1**. A few candidates would have benefited from repeating one of the experiments so that all their times decreased as volume of **FA1** increased.

VII and **VIII** The scoring of these accuracy marks tended to be centre-specific. This indicates that some candidates have enjoyed greater exposure to this type of practical exercise than others.

IX The most common error in calculating the rate was one of rounding. Candidates should be reminded that, for example, 500 ÷ 33 = 15.1515 would be 15.2 when rounded to 3 significant figures.

(b) I Almost all candidates assigned the correct variable to each axis and gained this mark.

II The majority correctly selected scales that led to plotted points covering more than half the available length on the two axes. Candidates should be encouraged to use simple scales such as 1, 2, 4 or 5 units to a 20 mm square wherever possible.

III A poor choice of scale usually led to errors in plotting. Some candidates were too imprecise for this mark to be awarded. Candidates should be reminded to use a sharp pencil and ensure any point that should be on a line is on that line and points within a square should be plotted in the correct portion of the square.

IV Lines of best fit may be straight or a smooth curve, but it is important in either case that anomalous points are clearly indicated. Candidates should either ring points they consider anomalous or otherwise label them. Many candidates simply joined the points for the first and second experiments without ensuring the other points were balanced on either side of the line.

(c) This mark was gained by a minority of candidates. Many candidates appeared to ignore their graphs, as a common response was that the rate was directly proportional to the concentration of **FA1** when there was no extrapolation of the line to the origin. The other common error was that rate increased as concentration increased without mention of 'proportional'.

(d) The first mark for use of the time for the second experiment and 2 s was commonly awarded. However, some candidates subtracted 2 instead of adding it. Hence, the rate calculated was greater than the minimum rate in their table in **(a)** or plotted in **(b)** thus not answering the question.

(e) (i) This question was challenging for candidates although a number correctly stated that less depth of solution would lead to a longer time for the print to be obscured. Many stated that, as the concentration was unchanged, the time would be unchanged without considering the dimensions of the beaker and its effect on the same total volume of reactants. Others linked an 'increase in surface area' (not appropriate) with a 'decrease in time taken' (incorrect).

(ii) Many candidates gave incomplete responses to this question as they simply stated that the rate would be 'very slow' because of the low concentration. This disregarded the '*never became invisible*' in the question. One misconception frequently seen was that the solution was too dilute for any reaction to occur. However, a small number of candidates gave excellent answers indicating they fully understood the experiment they had carried out.

Question 2

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

(a) I Although most candidates recorded the required data some wrote 'weight' instead of 'mass' or wrote the unit for temperature as C° so could not access the mark.

II Almost all candidates gave their balance readings to the same number of decimal places but many did not record thermometer readings to .0 or .5°C. It is important to indicate the precision of the apparatus used when recording experimental data.

III and **IV** Many candidates gained both marks for accuracy when comparing values of $\Delta T/m$. This was even true of some candidates who did not appear to add all the **FA 3** to the water as the mass of **FA3** recorded was considerably lower than the approximately 4 g supplied.

(b) (i) A significant number of candidates only quoted their answer to 2 s.f. even though the balance readings were to 2 d.p. so could not access the mark. Candidates should be reminded to read and employ the Quantitative Analysis instructions given at the start of the paper. Some candidates did not use the A_r values given in the Periodic Table. At AS and A Level it is expected that values correct to 1 d.p. will be used.

(ii) The most common error was to use the mass of **FA3** rather than the volume of solution (25 cm^3) in the 'mcΔT' calculation thus ignoring the information given below the stem of the question.

(iii) Candidates found this mark least accessible of the three available. While many calculated **(ii)** ÷ **(i)** successfully the conversion from J to kJ was not always matched by the units given. Only a minority gave the expected kJ mol^{-1} or J mol^{-1}. Although all candidates recorded a decrease in temperature in **(a)** some indicated the reaction was exothermic as a negative sign was given.

(c) Many answers lacked clarity with candidates suggesting, for example, using an '*accurate thermometer*' without stating that it should have smaller scale divisions. A digital thermometer is not necessarily more accurate so could not be awarded the marking point. Many candidates suggested using a lid or extra lagging for the cup to prevent heat loss even though they had recorded data in **(a)** indicating an endothermic reaction. Of those who correctly suggested using a greater mass of **FA3** some went on to also suggest using more water so were unable to access the marking point.

(d) This was possibly the most demanding question on the paper. Relatively few candidates acted on the information given that the concentration was correct. Most referred to the water of crystallisation diluting the solution and relating lower concentration to greater time for the 'disappearing print' reaction. Candidates were required to use the fact that the reaction in **Question 2** was endothermic and relate this to the method in **Question 1**.

Question 3

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

(a) (i) Almost all candidates noted effervescence but far fewer tested the gas evolved. Candidates should be aware that vigorous effervescence occurs in a small number of reactions:

- acid + metal
- acid + carbonate
- H_2O_2 + suitable catalyst.

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

(ii) Almost all candidates selected a named soluble barium salt as a reagent with many also selecting an acid. Those who selected nitric acid or hydrochloric acid usually gained both marks. However, a sizable number of candidates selected sulfuric acid so could access neither mark. Some candidates suggested using the barium salt solution in excess, which also could not be credited.

(iii) Identifying the cation proved difficult for many, but around half the candidates gained this mark. The most commonly seen incorrect responses were $(NH_4)_2SO_4$ and, even though the question asked for the formula of **FA4**, SO_4^{2-}.

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

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

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

(ii) Many incorrect responses were seen such as '*combustion*' and '*redox*'. Few candidates realised that, as heating was required for **FA5** to decompose, '*thermal*' had to be part of the answer.

(iii) Almost all candidates identified the cation as Cu^{2+} with many also correctly identifying CO_3^{2-}. Some candidates gave OH^- as the anion but this could only be credited if there was some evidence of condensation in **(b)(i)**. Also, some candidates selected NO_3^- as the anion without any evidence.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

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

General comments

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

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

Comments on specific questions

Question 1

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

(a) Most candidates gained most, if not all, of the marks in this section. However, several common errors were evident:

- burette readings not recorded for the rough titre
- burette readings recorded to 1 d.p. for the accurate titres
- performing a third accurate titration when the first two titres were within 0.10 cm^3.

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

Almost all candidates gained at least one mark for accuracy.

(b) Most candidates gained the mark for the mean with very few rounding errors or incorrect selection of titres seen.

(c)(i) While most candidates gave their answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the expected 3 or 4 significant figures some then gave the answer to **(c)(v)** to 2 s.f. so could not access the mark.

(ii) Many excellent answers were seen with only a small number of candidates mistakenly using 25.0 cm^3 instead of their value for **(b)** or omitting the use of 1000.

(iii) The mark for using the mole ratio from the equation was awarded to most candidates.

(iv) A large majority of candidates gained this mark. The errors were usually either using the M_r of $FeSO_4$ or not using the A_r value for Fe given in the Periodic Table. At AS and A Level it is expected that values correct to 1 d.p. will be used.

(v) The most common error was to omit the factor of 40. Candidates should be reminded to read the questions carefully as the answer to **(c)(iv)** concerned 25.0 cm^3 of **FB2** whereas the mass given in the identity of **FB2** on page 2 was for 1 dm^3 of solution.

(d) Correct answers to this section were rare: most candidates stated the student was correct, despite the reaction of $FeSO_4$ (aq) and NaOH (aq) featuring later in the paper. Some candidates stated the student was incorrect but did not give a correct reason. One common example was that there would be no colour change at the end point for the reaction between sulfuric acid and aqueous sodium hydroxide.

Question 2

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

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

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

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

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

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

(c) (i) Most gained this mark: errors were rounding the answer to 1 s.f. or using 10.0 cm^3 as the volume of **FB3** instead of their answer to **(b)**.

(ii) This part was also generally well answered and the mark was often awarded. However, some candidates multiplied their answer to **(i)** by 2 instead of dividing or divided this or the correct answer by 100 instead of multiplying.

(d) Most included the use of (Q =) mcΔT in their answer so gained at least one mark. There were various attempts at explaining 'm' and 'ΔT' but they often lacked the appropriate detail required to secure the mark. Careful reading of the question may have benefited some candidates as dividing Q by moles of water formed or by moles of sodium hydroxide were nearly as common as the correct use of moles of sulfuric acid or the answer to **(c)(ii)**.

Question 3

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

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

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

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

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

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

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

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

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

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

(ii) Most candidates gained at least one mark out of the two. The incorrect ions most commonly seen were Mg^{2+}, Cr^{3+} and Br^-. A few candidates ignored the instruction to give the formulae of the ions and wrote names, a small number of candidates confused cations with anions.

(iii) A minority of candidates gained this mark and many candidates left the line blank. The equation attempted more widely was for the precipitation of $BaSO_4$, some candidates omitted state symbols. Candidates that wrote the equation for producing $Fe(OH)_2$ often failed to balance the equation: some also omitted state symbols contrary to the instructions. Candidates from some centres were more proficient than others, indicating a greater exposure to the task.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

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

General comments

Candidates need to take time to study the instructions more closely both in terms of the practical method and in terms of initial instructions. Examples of where this was evident were the number of candidates who did not record burette readings for the rough titre in **2(a)** or who gave final answers to an inappropriate number of significant figures in **1(c)**.

Almost all centres correctly included the relevant supervisor script(s) and report(s).

Comments on specific questions

Question 1

Candidates generally found this question the most demanding even though it involves one of the quantitative techniques specified in the syllabus. Familiarity with these techniques, the associated calculations and an appreciation of inherent errors would aid candidates in an examination.

(a) Candidates should be reminded to record their data to reflect the precision of the apparatus used. Many were unable to access the first mark as their thermometer readings were given as integers. As the thermometers specified in the Confidential Instructions are graduated at 1°C the readings should all have been to .0 or .5°C.

The marks for accuracy tended to be centre-dependent. The candidates from some centres reported temperature changes that were closely grouped and agreed with the supervisor value. Most candidates completing the method gained at least one mark for accuracy.

(b) (i) Few candidates gained all three marks for this part. Common errors included:

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

(ii) More candidates gained this mark as they were able to read the intersect to 0.25 cm^3 accuracy. However, some candidates gave integer answers or quoted equal volumes of **FA1** and **FA2** when the intersect was not at 20.0 cm^3 so could not access the mark.

(c) (i) Most candidates reaching this section calculated the number of moles of sodium hydroxide correctly. However, not all noted the concentration of **FA2** was given as 2.00 mol dm^{-3} so their answers should reflect this level of accuracy.

(ii) Those successful in **(c)(i)** usually gained the mark for calculating the concentration of HZ in **FA1**.

(d) Most included the use of (Q =) mc∆T in their answer so gained at least one mark. There were various attempts at explaining 'm' and '∆T' but they often lacked the appropriate detail required to secure the mark. Successful candidates divided Q by moles of HZ or by **(c)(i)** so gained the mark.

Question 2

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

(a) Many candidates gained most, if not all, of the marks in this section. However, the usual errors were evident:

- burette readings not recorded for the rough titre
- burette readings recorded to 1 decimal place for the accurate titres
- performing a third accurate titration when the first two titres were within 0.10 cm^3.

Often, in the last case, the third titre value was outside the range allowed from either of the previous titres so the mark could not be awarded. Some candidates performed as many as seven titrations hence limited the time available for working on **Question 3**.

Most candidates gained at least one mark for accuracy.

(b) Most candidates gained the mark for the mean with very few rounding errors or incorrect selection of titres seen.

(c) (i) Candidates familiar with this type of calculation had no problem in providing answers correct to the expected 3 or 4 significant figures.

(ii) and **(iii)** These parts were correctly calculated by almost all candidates attempting them.

(iv) The most common error was to omit the dilution factor of 250 ÷ 10. Other errors were the use of 25.0 cm^3 instead of the volume calculated in **(b)** and not using 1000 to ensure the units were correct. However, the majority of candidates gained the mark.

(d) This section was demanding as it required a good understanding of the errors and uncertainties inherent in the two methods. Both methods involved use of apparatus or use of data that, it could be argued, made it suitable for selection as the more accurate but candidates only had to specify and explain one. All three statements were correctly selected and explained by some, though the third statement featured only rarely. Candidates from some centres left this part blank.

(e) This section was also demanding although there were several ways to achieve the mark. Again, candidates from some centres left this part blank.

The important points were the use of 60 (M_r of CH_3COOH) and a comparison of concentrations or masses dissolved or relative molecular masses.

Question 3

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

(a) Almost all candidates noted effervescence when testing **FA6** with Na_2CO_3 (aq) but fewer tested the gas evolved. There was a similar omission on testing **FA6** with Mg(s). Candidates should be aware that vigorous effervescence occurs in a small number of reactions:

- acid + metal
- acid + carbonate
- H_2O_2 + suitable catalyst.

Candidates should be reminded that '*gas produced*' is not an observation: it is a conclusion. Of those candidates testing the gas produced on addition of Na_2CO_3 (aq) to **FA 6** with limewater, some reported the limewater turning cloudy instead of cloudy white or white precipitate. 'Cloudy' is not a colour but indicates the previously transparent contents of the test-tube are now opaque.

The tests involving $AgNO_3$ (aq) and $Ba(NO_3)_2$ (aq) were generally well executed. However, the 'observations' with NaOH (aq) and **FA7** sometimes appeared contrived to fit with Mn^{2+} (aq) even though the question stated that only one of the cations was listed in the Qualitative Analysis Notes.

(b) The majority of candidates completing most of section **(a)** gained at least one mark when identifying the ions. The main errors seen were 'unknown' or NH_4^+ for **FA6** and Mn^{2+} and/or an anion identified for **FA7**. Candidates giving names instead of formulae were unable to access all the marks.

(c) Fewer candidates gained this mark and many candidates left the line blank. The equation attempted most widely was for the precipitation of $AgCl$ but some omitted state symbols. Few of those writing the equation for producing $Fe(OH)_3$ (s) balanced the equation: some also omitted state symbols contrary to the instructions. Some candidates ignored the instruction that the ionic equation should involve **FA5** ($FeCl_3$ (aq)) and gave the equation for the formation of a $BaSO_4$ precipitate. Candidates from some centres were more proficient than others indicating a greater exposure to the task.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- Many candidates write clearly, legibly and in understandable English. There were also some examples of legibility and grammatical problems on some scripts.
- On a chemistry paper it is essential for an examiner to be able to read the chemical symbols, the subscripts used in formulae and the charges of ions.
- Crossing out and overwriting so that, for example, a 2 and a 3 in a formula are both still visible and legible, is unacceptable. If a candidate wishes to change an answer, it should be crossed out thoroughly and then rewritten afterwards in another space, not written over the original answer.
- Where a question asks for a comparison of the properties of two substances or ions candidates should always make it clear which of the two they are describing in each part of their answer. The use of the word 'it' should be strongly discouraged in such answers.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.

General comments

Some of the questions set in table form, for example **Question 4 (a)** and **Question 4 (d)(ii)**, were not attempted by some candidates who otherwise performed well. This may be because those candidates were looking exclusively for answer lines. Candidates need to be encouraged to look for the marginal mark allocations, such as [1] and [2], to ensure they do not miss out questions.

Comments on specific questions

Question 1

(a) This question on factual recall of copper chemistry discriminated well, with all marks between [0] and [6] being commonly seen. The following points should be noted:

- Each of the two equations should always have been balanced for the number of ligand molecules involved.
- The question asks for ionic equations so spectator ions such as Na^+ and H^+ should not be included in the equations.
- The reaction between $(Cu(H_2O)_6)^{2+}$ and OH^- is acid-base. The hydroxide ions deprotonate two of the water ligands around each copper ion to form the copper hydroxide precipitate.
- $(CuCl_4)^{2-}$ is formed as an aqueous solution, not as a liquid and is yellow not green.
- The question asked twice for the 'state of the copper-containing product', i.e. (s), (l), (g) or (aq). This is not the same as the 'oxidation state of the copper-containing product'.

(b) Many good answers were seen, involving a calculation showing that the 0.303 g sample contained 0.159 g of chlorine and 0.144 g of sulfur. There were many other possible approaches that involved correct chemistry.

The following were all common:

- The candidate was unable to start the calculation.
- Calculation of 0.0012 moles of Ag^+ but no further (no mark scored).
- Calculation of 0.0048 moles of Cl^- but no further (one mark scored).
- Calculations all the way through to SCl (three marks scored).

Question 2

(a) Many candidates knew the formula of strontium nitrate, the identity of the products and could balance the equation.

(b) Most candidates had prepared well for this question. It was common to see a statement regarding increasing stability and increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion, was less frequently seen. Some candidates suggested there was polarisation of the cation, or that polarisation was caused 'by the anion'.

(c) (i) This question was often found difficult, in particular many candidates did not state clearly that 'Ca^{2+} has a smaller ionic radius than Ba^{2+}'. This question is a good example of where 'it' is ambiguous. 'It has a smaller ionic radius' could refer to Ca^{2+}, Ba^{2+} or NH_2^-.

(ii) This was generally answered well. Some candidates did not attempt to balance the equation.

(d) Many candidates found this question difficult. Better performing candidates realised that the amide ion is comparable with the water molecule and used this to predict a bond angle of 104.5° and to provide an explanation based on VSEPR theory. Some very good answers were seen, many of which were well supported by a dot-and-cross diagram of the amide ion, or a clear diagram showing two lone pairs and two bond pairs.

A significant number of answers were also seen in which:

- The bond angle of the $Ba(NH_2)_2$ formula unit was discussed, not the bond angle of the amide ion
- VSEPR theory was not used at all
- It was stated that the amide ion has one lone pair, like the ammonia molecule
- It was stated that the amide ion has one lone pair and one lone unpaired electron, forgetting the negative charge.

Question 3

(a) This was answered well by many candidates. The commonest error was that no attempt was made at balancing.

(b) (i) Many good, clearly explained answers were seen.

Errors in other answers included:

- A description of this particular reaction which did not refer to oxidation or reduction.
- A correct definition of disproportionation that did not use this reaction as an example.

(ii) This question was found to be very difficult. Many candidates did not appreciate that the two half-equations that can be used to describe a redox reaction should include one half-equation in which a species gains an electron, or electrons, and one half-equation in which a species loses an electron, or electrons.

In a description of changing oxidation numbers, as in **Question 3 (b)(i)**, better performing candidates noted that the 'chlorine in oxidation state +4 goes to chlorine in oxidation states +3 and +5'. Chemical equations involving Cl^{3+}', Cl^{4+} and Cl^{5+} were not acceptable here.

(c) (i) This was usually answered well and the award of full credit was common. Better performing candidates tended to write an electron as e^-, not just as e, as this helps to confirm that a half equation is balanced for electric charge.

The errors seen included:

- An ionic equation for the reduction of Li^+, not for the oxidation of Li.
- Unbalanced overall equations involving one Li atom and one I_2 molecule.

(ii) This mark was usually awarded.

(iii) This question was highly discriminating. Many candidates worked through in very few lines to the correct answer. However, a similar number of candidates were either unable to begin the calculation or could only get as far as the number of moles of lithium.

Some candidates used the Avogadro constant and the electronic change rather than the Faraday constant. A correct answer was possible by this method, and was very occasionally seen, but this was rare.

Some candidates believed that two Faradays of charge is necessary to use up one mole of the lithium electrode. If they worked through to 1.1×10^8 s they scored two marks.

Question 4

(a) This was usually answered well. A small number of candidates thought the first diagram was of a d orbital, presumably dz^2.

(b) It was rare to see 'cadmium doesn't form an ion with an incomplete d subshell'. A lot of answers were seen in terms of d orbitals. An answer that said 'in both cadmium ions there is a full d-orbital' did not score. This answer could be applied to Cu^{2+}, which actually has four filled d orbitals, however copper is a transition element. Copper is a transition element because **every** d orbital cannot be said to be filled in Cu^{2+}.

(c) (i) This was usually answered well.

(ii) This was often answered well,.

The errors most commonly seen were:

- Diagrams without any 3-D bonds.
- Diagrams in which 3-D bonds were drawn but where the complex could not be octahedral.
- The use of 'O_2H' for the formula of one or more of the water ligands.

(d) (i) This mark was rarely awarded.

(ii) Many candidates did not know that an equilibrium constant like K_{stab} is affected by temperature.

Some candidates did not describe a clear link between the exothermic forward reaction (or endothermic backward reaction) and the direction in which the position of equilibrium will move.

(iii) Most candidates answered this correctly.

(e) This was answered well by many candidates. No credit was given to equations that did not include the formation of an OH^- ion, as such equations on their own do not explain the formation of the alkaline solution asked for in the question.

Some candidates wrongly showed the formation of ammonium ions, NH_4^+.

(f) (i) This was answered well by many candidates. The most common errors were:

- An incorrect formula for ethanoyl chloride
- A product that was a primary amide
- Forgetting the HCl second product.

(ii) This was rarely answered correctly. It is possible that the unusual context of the condensation reaction confused many candidates.

Question 5

(a) (i) A key component to the best answers was the clear explanation of how the changing concentration of ammonia affected the rate of experiments 1 and 2. This justified the conclusion that the reaction is first order with respect to (ClO^-).

(ii) Most candidates were able to do this correctly. Some candidates omitted the rate constant.

(iii) Most candidates were able to do this correctly. Some ignored the instruction to use the results of experiment 1. Nearly all candidates used the correct representation for units.

(iv) The great majority of candidates showed that *k* increases as T increases. The most common incorrect graphs were:

- Showing *k* as constant for all values of T
- The same shape as an 'amount of product vs time' graph.

(b) (i) Many candidates overcomplicated their answer to this question. The most straightforward method is to plot (I^-) against time and then to show that the graph has a constant half-life. It is possible to explain how the data described in the question can be used to produce a concentration-rate graph, and then to explain how this graph can be used to demonstrate the first order kinetics, but this is significantly more difficult.

(ii) This question was usually answered well.

(iii) Many good answers were seen; others were spoiled by internal errors of detail. An example of this is an answer that correctly identified step 2, correctly stated that iodine was oxidised, and then stated that *chloride* ions were reduced.

Question 6

(a) The most common mistake was to tick that enthalpy of formation is always negative.

(b) This was usually answered well. The most common mistakes were to describe ions not atoms, and to omit the reference to the amount of one mole (of gaseous atoms formed).

(c) This question was found to be difficult. Many errors were often introduced when constructing the cycle, such as arrows in the incorrect directions, unbalanced changes e.g. $Br_2(g) \rightarrow Br(g)$, incorrect state symbols and the introduction of ionic species. In the calculation, candidates often did not double the +112 and many answers were algebraically wrong or were stated with an incorrect sign.

(d) Candidates did not perform well on this question. Many responses focused on the strength of the covalent bonds within the halogen molecules, rather than on the strength of the van der Waals forces between molecules.

(e) (i) This was often answered well. Candidates should be wary of using a term like *hydrated* to help to define 'enthalpy change of hydration'. Those candidates who described the one mole of gaseous ions as dissolving in water, or forming an aqueous solution, submitted a much better answer.

(ii) This discriminated well. Approximately half the candidates recognised the importance of the lower ionic radius of Br^-. It was less common to see that this smaller radius results in greater attractive forces with water molecules.

Question 7

(a) (i) Candidates performed well on this question.

(ii) Candidates found this question very difficult. The bond angle in benzene was better known than the bond angle in cyclohexane. Many candidates attempted explanations that had no bearing on the bond angles or gave answers that effectively restated the bond angles. Some answers erroneously referred to lone pairs on carbon atoms.

(b) (i) Those who had learned the electrophilic substitution mechanism found this to be an accessible question.

Where marks were lost the reasons included:

- The curly arrow from the benzene in step one did not go to the sulfur atom (which is seen bonded to the benzene ring in the benzenesulfonic acid)
- The intermediate was drawn with a + charge within the ring and a + charge on the $–SO_3H$ group
- The curly arrow in the intermediate started on the H not on the C–H bond
- No H^+ ion was shown with the benzenesulfonic acid at the end of the mechanism.

(ii) This question was often answered well.

(c) This was often correct. Common errors included:

- The wrong formula for the chloroalkane
- Including (aq) as a condition
- Describing the mechanism as ‘Friedel-Crafts’ or ‘alkylation’.

(d) (i) Candidates typically correctly answered this question. On a very small number of scripts the square brackets were omitted, or the ionic charges were written outside the square brackets.

(ii) This answer was usually correct.

(e) This was answered well by the majority of candidates. The link between pH and (H^+) and the use of the K_a expression to find the value of K_a, was generally well understood.

Question 8

(a) (i) This question was generally answered well.

(ii) Many candidates were able to work out the formulae of the two fragments, but did not appreciate that the + charge on the left of the arrow had to be balanced with a single plus charge on the right.

(b) This factually based question was highly discriminating. Many candidates confused the role of $CDCl_3$ with that of D_2O.

(c) (i) Many candidates found this question difficult. Two common errors were:

- Not using the relative peak areas (integration numbers) to identify the number of protons in each environment.
- Not appreciating that the splitting pattern of the peaks at δ1.2 and δ3.5 show that these peaks signify the presence of an ethyl group.

(ii) This was found to be very difficult by many candidates.

(d) This question was found to be very difficult by many candidates. Butyl methanoate and ethyl propanoate are two incorrect answers that were regularly seen.

(e) (i) This was answered well. It should be noted that the four groups and the carbon atom are joined by chemical bonds, loose terms like ‘surrounded by’ should not be used.

(ii) This question was answered well.

Question 9

(a) This was a demanding question. The relative rates of hydrolysis was often given. The explanation required careful wording by the candidates. The best responses focused on the strength of the C-C*l* bond. This bond is:

- Weakened by the negative inductive effect of the carbonyl oxygen atom.
- Strengthened by the positive inductive effect of the ethyl group.
- Greatly strengthened by the overlap between the p-orbital on the chlorine atom and the π electrons in the benzene ring, causing some degree of double bond character.

(b) (i) Many answers focused on the meaning of the word 'weak' and did not also explain what a base is.

(ii) This question was found to be difficult. Common errors included:

- Chlorination of the benzene ring
- The addition of hydrogen to one or both nitrogen atoms without also adding a + charge
- The addition of a + charge to one or both nitrogen atoms without also adding hydrogen
- The drawing of a covalent bond from one or both nitrogen atoms to a chlorine atom.

(c) (i) This was found to be difficult. The breaking and reformation of π bonds was not often appreciated.

(ii) Most candidates knew what was meant by two repeat units. Errors in the amide link were rare. The issues arising from candidates' use of skeletal formula, which have been highlighted in previous reports of this type, arose only very rarely. This was because candidates wisely avoided the use of skeletal formulae on this question.

(d) Candidate responses were usually correct for this question.

(e) Many candidates stated correctly that polyamides can be hydrolysed, but a much smaller number stated that polyalkenes cannot be hydrolysed. Both statements were required.

(f) (i) This question discriminated well.

(ii) This question was often answered well. Some common errors from previous years, such as including (aq) in step 1, or omitting to state that sulfuric acid must be concentrated and hot in step 3, were less common this year.

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.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who had prepared well for the examination were able to attempt all the questions. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

(a) **(i)** Most candidates answered this well. Common errors were $3s^23p^63d^{10}4s^1$ and $3s^23p^63d^74s^2$.

(ii) This was well known. $[Cu(H_2O)_6]^{2+}$ being pink and $CuCl_4^{2-}$ green were common errors.

(iii) Many candidates described why complexes are coloured instead of why metal ions with different ligands can have different colours.

(b) This proved difficult for some candidates. Some candidates stated that they have a full d-orbital instead of every d-orbital is full. A number of candidates stated that no d-d splitting occurs rather than no d-d transition can occur.

(c) **(i)** Most candidates gave the correct answer.

(ii) This proved challenging for many candidates and answers often lacked clarity or used le Chatelier's principle in their explanation. Only a small number of candidates gave a suitable explanation. Common errors included just comparing the two equilibrium constants or stating that $[Ag^+]$ would increase.

(iii) This question was usually fully credited.

(iv) Common incorrect answers seen were K_{stab}/K_{sp} and K_{sp}/K_{stab}.

(d) This was well known.

(e) **(i)** Many fully correct answers were seen. The most common omissions were the label for the platinum electrode and pressure (1 atm) for hydrogen gas, also a small number did not have their salt bridge immersed in the two solutions.

(ii) This was generally well answered.

Question 2

(a) A common error was forming CO_2 and ½O_2 as products.

(b) The trend and its explanation were well understood by candidates.

(c) Many candidates correctly quoted the ionic radii for these cations and the trend. Common errors were quoting atomic radii or atomic number or giving the reverse stability trend.

(d) Many candidates answered this well, gaining full credit. Some thought dolomite was pure $CaMg(CO_3)_2$ and just calculated the moles of dolomite without any reasoning, which gained no credit.

Question 3

(a) Most candidates gave a correct answer.

(b) (i) Many candidates understood the idea of a transition element but some definitions often lacked precision. A common example of imprecision in candidate's definitions was stating that a transition element 'is an element with an incomplete d sub-shell and forms one or more ions'.

(ii) Most candidates answered this question correctly.

(c) Most candidates gave the correct formulae of the two oxides, but often omitted the oxidation number for each iron.

(d) This was generally well answered. Common errors were incorrect use of brackets, for example $[Ni(CO_4)]$, and 2– charge for the nickel complex.

(e) (i) Most candidates recognised geometrical isomerism. However, candidates stating optical isomerism for this question was a common error.

(ii) Many fully correct answers were seen. Common errors were due to use of incorrect formulae for ligands: O_2H and Cl_2.

(f) (i) This was often answered well. Common errors included putting ionic charges outside the final set of square brackets, e.g. $[Cu(H_2O)_6]^{2+}$ or $K_{stab} = [[Cu(H_2O)_4(NH_3)_2]]^{2+}/[[Cu(H_2O)_6]]^{2+}[NH_3]^2$. The units were usually correct.

(ii) Most candidates found this challenging. Some very good answers were seen, although many candidates did not answer in terms of moles of species on the reactant side and product side.

(iii) Most candidates gave a correct answer.

Question 4

(a) Many fully correct answers were seen.

(b) (i) Many candidates gave the correct answer. A common error was omitting s^{-1} in the units.

(ii) This was not well known. Many thought the rate constant was independent of temperature.

(c) Some answers lacked sufficient detail, for example when to draw a tangent to the curve (time = 0 sec). Weaker responses described how to calculate a half-life to determine the order.

(d) This was generally well answered. Many incorrect answers resembled graphs associated with investigating rates of reaction.

(e) (i) Most candidates gave a correct answer.

(ii) This was often answered well. Common errors included unbalanced equations and candidates omitting the catalyst was regenerated in step 3.

Question 5

(a) This was not well known. Many candidates thought enthalpy of neutralisation could be either exothermic or endothermic.

(b) Many candidates gave a correct answer. Common errors were omitting ‘dissolving in water’ or stating that the solute was ‘dissolving in a solution’.

(c) This question discriminated well. Many correct answers were seen. Common errors were incorrect signs in their calculation, not multiplying 251 by 3 or including additional data such as the first ionisation energy of K.

(d) Many candidates gained credit, although a significant number did not link the difference in ionic radii to the strength of the attraction between ions.

(e) (i) Most candidates gave a correct equation.

(ii) This was generally well answered.

Question 6

(a) Most candidates stated benzene had a planar structure with a bond angle of 120° or the carbon atoms were sp^2 hybridised. However, many answers lacked sufficient detail and did not refer to how the sigma and pi-bonds are formed. Some did not state that the electrons in the pi-bonds were delocalised and a number described the Kekule structure of benzene (alternating single and double carbon to carbon bonds).

(b) (i) This was usually well known. A common error was omitting a charge in one of the products.

(ii) Some very good answers were seen. The intermediate was normally awarded. However, many candidates did not draw curly arrows with enough precision and H^+ was normally omitted as a final product.

(iii) This question was usually fully credited.

(iv) Many candidates stated the type of reaction was reduction. A common error was the omission of ‘concentrated’ with hydrochloric acid.

(c) (i) Many correct answers were seen. Common errors were $C_{15}H_{15}N$ and $C_{15}H_{15}O_2$.

(ii) This was generally well answered. Common errors were carboxyl and amide.

(iii) This calculation was done well by many. A common error was over rounding during the calculation.

(d) Most candidates found this challenging. Many candidates recognised the methyl group was an electron donating group, although only a few discussed the subsequent stability of the two carbocations.

Question 7

(a) (i) Most candidates gave a correct answer.

(ii) This proved difficult for many candidates. Some incorrectly predicted R_f values would decrease/not change. Those that did correctly predict an increase often did not sufficiently explain the increase in solubility using a more polar solvent.

(b) (i) This was generally well answered. Common errors were unbalanced charges in their equations, forming the acyl chloride and the omission of water.

(ii) Most candidates gave the correct structure of the zwitterion. A common error was suggesting that water provided the H^+ ion to protonate the NH_2 group and OH^- ion to deprotonate the CO_2H group.

(c) Most candidates gave a correct answer.

(d) (i) Most candidates correctly identified the mechanism, although many omitted the need for pressure.

(ii) Many candidates gave the correct trend and linked this to the electronegativity of the chlorine atoms. However, only a small number explained that the O-H bond would be weakened and become easier to ionise.

(e) Most candidates were able to identify one or two of the isomers – normally as the dipeptides. The ester was least commonly awarded.

Question 8

(a) Many candidates answered this well. Common errors were omitting 'di' or not numbering correctly.

(b) (i) This was usually well known. Common errors were four peaks in carbon-13 and two peaks in the proton NMR.

(ii) This was generally well answered and the OH proton identified. Many answers lacked clarity and referred to compounds just reacting with D_2O.

(c) Some very good answers were seen. Most candidates correctly identified the product from the reaction with Na and Br_2. The other reactions were less well known. Common errors included:

- the Friedel-Crafts ring substituted product with CH_3COCl
- the substitution of the OH in the ring with Br for the reaction with Br_2
- the substitution of the OH or Cl in the ring with -N=N-C_6H_5 for the reaction with benzene diazonium chloride
- the retaining the N≡N in the substituted product with benzene diazonium chloride.

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

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Many candidates write clearly, legibly and in understandable English. There were also some examples of legibility and grammatical problems on some scripts.
- On a chemistry paper it is essential for an examiner to be able to read the chemical symbols, the subscripts used in formulae and the charges of ions.
- Crossing out and overwriting so that, for example, a 2 and a 3 in a formula are both still visible and legible, is unacceptable. If a candidate wishes to change an answer, it should be crossed out thoroughly and then rewritten afterwards in another space, not written over the original answer.
- Where a question asks for a comparison of the properties of two substances or ions candidates should always make it clear which of the two they are describing in each part of their answer. The use of the word 'it' should be strongly discouraged in such answers.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.

General comments

Some of the questions set in table form, for example **Question 4 (a)** and **Question 4 (d)(ii)**, were not attempted by some candidates who otherwise performed well. This may be because those candidates were looking exclusively for answer lines. Candidates need to be encouraged to look for the marginal mark allocations, such as [1] and [2], to ensure they do not miss out questions.

Comments on specific questions

Question 1

(a) This question on factual recall of copper chemistry discriminated well, with all marks between [0] and [6] being commonly seen. The following points should be noted:

- Each of the two equations should always have been balanced for the number of ligand molecules involved.
- The question asks for ionic equations so spectator ions such as Na^+ and H^+ should not be included in the equations.
- The reaction between $(Cu(H_2O)_6)^{2+}$ and OH^- is acid-base. The hydroxide ions deprotonate two of the water ligands around each copper ion to form the copper hydroxide precipitate.
- $(CuCl_4)^{2-}$ is formed as an aqueous solution, not as a liquid and is yellow not green.
- The question asked twice for the 'state of the copper-containing product', i.e. (s), (l), (g) or (aq). This is not the same as the 'oxidation state of the copper-containing product'.

(b) Many good answers were seen, involving a calculation showing that the 0.303 g sample contained 0.159 g of chlorine and 0.144 g of sulfur. There were many other possible approaches that involved correct chemistry.

The following were all common:

- The candidate was unable to start the calculation.
- Calculation of 0.0012 moles of Ag^+ but no further (no mark scored).
- Calculation of 0.0048 moles of Cl^- but no further (one mark scored).
- Calculations all the way through to SCl (three marks scored).

Question 2

(a) Many candidates knew the formula of strontium nitrate, the identity of the products and could balance the equation.

(b) Most candidates had prepared well for this question. It was common to see a statement regarding increasing stability and increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion, was less frequently seen. Some candidates suggested there was polarisation of the cation, or that polarisation was caused 'by the anion'.

(c) (i) This question was often found difficult, in particular many candidates did not state clearly that 'Ca^{2+} has a smaller ionic radius than Ba^{2+}'. This question is a good example of where 'it' is ambiguous. 'It has a smaller ionic radius' could refer to Ca^{2+}, Ba^{2+} or NH_2^-.

(ii) This was generally answered well. Some candidates did not attempt to balance the equation.

(d) Many candidates found this question difficult. Better performing candidates realised that the amide ion is comparable with the water molecule and used this to predict a bond angle of 104.5° and to provide an explanation based on VSEPR theory. Some very good answers were seen, many of which were well supported by a dot-and-cross diagram of the amide ion, or a clear diagram showing two lone pairs and two bond pairs.

A significant number of answers were also seen in which:

- The bond angle of the $Ba(NH_2)_2$ formula unit was discussed, not the bond angle of the amide ion
- VSEPR theory was not used at all
- It was stated that the amide ion has one lone pair, like the ammonia molecule
- It was stated that the amide ion has one lone pair and one lone unpaired electron, forgetting the negative charge.

Question 3

(a) This was answered well by many candidates. The commonest error was that no attempt was made at balancing.

(b) (i) Many good, clearly explained answers were seen.

Errors in other answers included:

- A description of this particular reaction which did not refer to oxidation or reduction.
- A correct definition of disproportionation that did not use this reaction as an example.

(ii) This question was found to be very difficult. Many candidates did not appreciate that the two half-equations that can be used to describe a redox reaction should include one half-equation in which a species gains an electron, or electrons, and one half-equation in which a species loses an electron, or electrons.

In a description of changing oxidation numbers, as in **Question 3 (b)(i)**, better performing candidates noted that the 'chlorine in oxidation state +4 goes to chlorine in oxidation states +3 and +5'. Chemical equations involving Cl^{3+}, Cl^{4+} and Cl^{5+} were not acceptable here.

(c) (i) This was usually answered well and the award of full credit was common. Better performing candidates tended to write an electron as e^-, not just as e, as this helps to confirm that a half equation is balanced for electric charge.

The errors seen included:

- An ionic equation for the reduction of Li^+, not for the oxidation of Li.
- Unbalanced overall equations involving one Li atom and one I_2 molecule.

(ii) This mark was usually awarded.

(iii) This question was highly discriminating. Many candidates worked through in very few lines to the correct answer. However, a similar number of candidates were either unable to begin the calculation or could only get as far as the number of moles of lithium.

Some candidates used the Avogadro constant and the electronic change rather than the Faraday constant. A correct answer was possible by this method, and was very occasionally seen, but this was rare.

Some candidates believed that two Faradays of charge is necessary to use up one mole of the lithium electrode. If they worked through to 1.1×10^8 s they scored two marks.

Question 4

(a) This was usually answered well. A small number of candidates thought the first diagram was of a d orbital, presumably dz^2.

(b) It was rare to see 'cadmium doesn't form an ion with an incomplete d subshell'. A lot of answers were seen in terms of d orbitals. An answer that said 'in both cadmium ions there is a full d-orbital' did not score. This answer could be applied to Cu^{2+}, which actually has four filled d orbitals, however copper is a transition element. Copper is a transition element because **every** d orbital cannot be said to be filled in Cu^{2+}.

(c) (i) This was usually answered well.

(ii) This was often answered well,.

The errors most commonly seen were:

- Diagrams without any 3-D bonds.
- Diagrams in which 3-D bonds were drawn but where the complex could not be octahedral.
- The use of 'O_2H' for the formula of one or more of the water ligands.

(d) (i) This mark was rarely awarded.

(ii) Many candidates did not know that an equilibrium constant like K_{stab} is affected by temperature.

Some candidates did not describe a clear link between the exothermic forward reaction (or endothermic backward reaction) and the direction in which the position of equilibrium will move.

(iii) Most candidates answered this correctly.

(e) This was answered well by many candidates. No credit was given to equations that did not include the formation of an OH^- ion, as such equations on their own do not explain the formation of the alkaline solution asked for in the question.

Some candidates wrongly showed the formation of ammonium ions, NH_4^+.

(f) (i) This was answered well by many candidates. The most common errors were:

- An incorrect formula for ethanoyl chloride
- A product that was a primary amide
- Forgetting the HCl second product.

(ii) This was rarely answered correctly. It is possible that the unusual context of the condensation reaction confused many candidates.

Question 5

(a) (i) A key component to the best answers was the clear explanation of how the changing concentration of ammonia affected the rate of experiments 1 and 2. This justified the conclusion that the reaction is first order with respect to (ClO^-).

(ii) Most candidates were able to do this correctly. Some candidates omitted the rate constant.

(iii) Most candidates were able to do this correctly. Some ignored the instruction to use the results of experiment 1. Nearly all candidates used the correct representation for units.

(iv) The great majority of candidates showed that *k* increases as T increases. The most common incorrect graphs were:

- Showing *k* as constant for all values of T
- The same shape as an 'amount of product vs time' graph.

(b) (i) Many candidates overcomplicated their answer to this question. The most straightforward method is to plot (I^-) against time and then to show that the graph has a constant half-life. It is possible to explain how the data described in the question can be used to produce a concentration-rate graph, and then to explain how this graph can be used to demonstrate the first order kinetics, but this is significantly more difficult.

(ii) This question was usually answered well.

(iii) Many good answers were seen; others were spoiled by internal errors of detail. An example of this is an answer that correctly identified step 2, correctly stated that iodine was oxidised, and then stated that *chloride* ions were reduced.

Question 6

(a) The most common mistake was to tick that enthalpy of formation is always negative.

(b) This was usually answered well. The most common mistakes were to describe ions not atoms, and to omit the reference to the amount of one mole (of gaseous atoms formed).

(c) This question was found to be difficult. Many errors were often introduced when constructing the cycle, such as arrows in the incorrect directions, unbalanced changes e.g. $Br_2(g) \rightarrow Br(g)$, incorrect state symbols and the introduction of ionic species. In the calculation, candidates often did not double the +112 and many answers were algebraically wrong or were stated with an incorrect sign.

(d) Candidates did not perform well on this question. Many responses focused on the strength of the covalent bonds within the halogen molecules, rather than on the strength of the van der Waals forces between molecules.

(e) (i) This was often answered well. Candidates should be wary of using a term like *hydrated* to help to define 'enthalpy change of hydration'. Those candidates who described the one mole of gaseous ions as dissolving in water, or forming an aqueous solution, submitted a much better answer.

(ii) This discriminated well. Approximately half the candidates recognised the importance of the lower ionic radius of Br^-. It was less common to see that this smaller radius results in greater attractive forces with water molecules.

Question 7

(a) (i) Candidates performed well on this question.

(ii) Candidates found this question very difficult. The bond angle in benzene was better known than the bond angle in cyclohexane. Many candidates attempted explanations that had no bearing on the bond angles or gave answers that effectively restated the bond angles. Some answers erroneously referred to lone pairs on carbon atoms.

(b) (i) Those who had learned the electrophilic substitution mechanism found this to be an accessible question.

Where marks were lost the reasons included:

- The curly arrow from the benzene in step one did not go to the sulfur atom (which is seen bonded to the benzene ring in the benzenesulfonic acid)
- The intermediate was drawn with a + charge within the ring and a + charge on the $–SO_3H$ group
- The curly arrow in the intermediate started on the H not on the C–H bond
- No H^+ ion was shown with the benzenesulfonic acid at the end of the mechanism.

(ii) This question was often answered well.

(c) This was often correct. Common errors included:

- The wrong formula for the chloroalkane
- Including (aq) as a condition
- Describing the mechanism as 'Friedel-Crafts' or 'alkylation'.

(d) (i) Candidates typically correctly answered this question. On a very small number of scripts the square brackets were omitted, or the ionic charges were written outside the square brackets.

(ii) This answer was usually correct.

(e) This was answered well by the majority of candidates. The link between pH and (H^+) and the use of the K_a expression to find the value of K_a, was generally well understood.

Question 8

(a) (i) This question was generally answered well.

(ii) Many candidates were able to work out the formulae of the two fragments, but did not appreciate that the + charge on the left of the arrow had to be balanced with a single plus charge on the right.

(b) This factually based question was highly discriminating. Many candidates confused the role of $CDCl_3$ with that of D_2O.

(c) (i) Many candidates found this question difficult. Two common errors were:

- Not using the relative peak areas (integration numbers) to identify the number of protons in each environment.
- Not appreciating that the splitting pattern of the peaks at δ1.2 and δ3.5 show that these peaks signify the presence of an ethyl group.

(ii) This was found to be very difficult by many candidates.

(d) This question was found to be very difficult by many candidates. Butyl methanoate and ethyl propanoate are two incorrect answers that were regularly seen.

(e) (i) This was answered well. It should be noted that the four groups and the carbon atom are joined by chemical bonds, loose terms like 'surrounded by' should not be used.

(ii) This question was answered well.

Question 9

(a) This was a demanding question. The relative rates of hydrolysis was often given. The explanation required careful wording by the candidates. The best responses focused on the strength of the C-C*l* bond. This bond is:

- Weakened by the negative inductive effect of the carbonyl oxygen atom.
- Strengthened by the positive inductive effect of the ethyl group.
- Greatly strengthened by the overlap between the p-orbital on the chlorine atom and the π electrons in the benzene ring, causing some degree of double bond character.

(b) (i) Many answers focused on the meaning of the word ‘weak’ and did not also explain what a base is.

(ii) This question was found to be difficult. Common errors included:

- Chlorination of the benzene ring
- The addition of hydrogen to one or both nitrogen atoms without also adding a + charge
- The addition of a + charge to one or both nitrogen atoms without also adding hydrogen
- The drawing of a covalent bond from one or both nitrogen atoms to a chlorine atom.

(c) (i) This was found to be difficult. The breaking and reformation of π bonds was not often appreciated.

(ii) Most candidates knew what was meant by two repeat units. Errors in the amide link were rare. The issues arising from candidates’ use of skeletal formula, which have been highlighted in previous reports of this type, arose only very rarely. This was because candidates wisely avoided the use of skeletal formulae on this question.

(d) Candidate responses were usually correct for this question.

(e) Many candidates stated correctly that polyamides can be hydrolysed, but a much smaller number stated that polyalkenes cannot be hydrolysed. Both statements were required.

(f) (i) This question discriminated well.

(ii) This question was often answered well. Some common errors from previous years, such as including (aq) in step 1, or omitting to state that sulfuric acid must be concentrated and hot in step 3, were less common this year.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- Better performing candidates gave numerical answers to the required number of decimal places or significant figures, as required by the questions.
- Some candidates need to improve of the legibility of their answers.
- Candidates should set out calculations in a logical sequence, which enables credit for error carried forward to be applied where necessary.

General comments

There was a tendency to over approximate, truncate and incorrectly round, particularly approximating within a calculation. Such approximation usually leads to increasing divergence of result and is particularly significant in multistage calculations as in **Question 2(b)(iii)**. Candidates should be advised to carry through values held on their calculators, thus avoiding approximating divergence.

The numerical questions, **Questions 1(b)(i)**, **2(a)(i)** and **2(b)(iii)** were answered better than the textual chemical questions.

There was evidence of a lack of basic chemical knowledge from some candidates. This was displayed in, for example, **Question 2(a)(i)** where the '3' in the equation in front of the propan-2-ol was included in the M_r, as well as in the stoichiometric calculation. This was also seen in **Question 2(a)(iv)**, where unsuitable reagents such as lithium tetrahydroborate or silver nitrate were proposed. Poor diagrams were seen in **Question 2(a)(ii)**. This suggests that some candidates would benefit from a greater exposure to apparatus, chemicals and their reactions through realistic laboratory work.

Some inconsistent answers were seen where a moment's reflection on the candidates' part may have exposed their error. Thus in **Question 1(b)(i)**, a popular incorrect answer of using 250 cm^3 of manganese(II) solution to prepare (as in the question) a 100 cm^3 final solution.

There was a tendency to over-answer, perhaps in the hope of something being correct. This approach is to be avoided, as numerous answers often contradict each other. In **Question 2(b)(i)**, an answer such as 'filtration would be faster, more efficient and would give a dry sample of **X**' contains a correct and an incorrect response. Contradictory answers were also common in **Questions 1(d)(ii)**, **1(g)**, **2(a)(ii)** and **2(b)(iv)**. As such, candidates should avoid over-answering in order to minimise the introduction of contradictions.

Candidates should be discouraged from giving non-specific responses. For example, as in **Question 2(b)(ii)** 'heat it and measure the change'; in **Question 1(d)(ii)** 'the concentration was incorrectly prepared resulting in a higher or lower actual concentration' which has no effective meaning. Other statements such as, 'the temperature was wrong' or 'the candidate had an incorrect concentration' also have no real meaning.

Comments on specific questions

Question 1

(a) The requirement for three answers was usually satisfied and over half of the candidates did well. A few candidates labelled the voltmeter as an ammeter or power supply. The most common error was to incorrectly label the copper(II) concentration as 0.500 mol dm^{-3}, presumably taking a lead from the concentration of manganese(II), whereas the question stated the copper(II)/copper half-cell as a standard half-cell, which would feature 1.000 mol dm^{-3} solutions.

(b) (i) This standard, dilution question was correctly answered by most of the candidates. A popular incorrect response was 250 cm^3, which was at odds with the clear question requirement to produce a 100 cm^3 solution.

(ii) This question required a two-part answer. Firstly, accurately measuring a solution volume then secondly accurately diluting it – the emphasis being on accurate. The best way of measuring the volume from **(b)(i)** is by delivering it from a burette. Measuring cylinders are insufficiently accurate for this procedure. Pipettes could be used, provided they were of a size generally available, for example the use of a 20 cm^3 pipette twice. Pipettes with no stated volume were not accepted nor were 40 cm^3 pipettes. After delivering the solution from the burette, some candidates erroneously rinsed the burette with water, which was added to the original delivery. Some contradictory answers appeared here, such as 'use a burette or a measuring cylinder'.

A significant number of candidates confused this procedure with that for making a solution from a solid so did not deliver their volume into the 100 cm^3 volumetric flask. These candidates chose a beaker or flask into which they added some water, stirred then transferred to the volumetric flask. This unnecessary procedure was accepted provided distilled water was used, the beaker was washed with distilled water and the washings added to the volumetric flask, and the volume did not exceed 100 cm^3.

The dilution to 100 cm^3 in the volumetric flask was done better. However, many candidates did not specify distilled water. Some erroneously added 60 cm^3, often by measuring cylinder and others had 'make to 100 cm^3' without stating that the only way this could be done was by making to the mark in a volumetric flask.

(iii) The table had simple calculations, including correctly quoting to either two or three decimal places, at which virtually all candidates succeeded. Three values of log(Mn^{2+}) were often truncated rather than correctly rounded. For example, the calculator value from the second table concentration was –0.6989700043, which was typically truncated to –0.69 rather than correctly rounded to –0.70. The other common error was to omit the last digit if it was zero, for example –1.210 was given as –1.21.

(c) The plotting of the data was generally very well done, as was the line. Most mis-plots were quite close to being correct but outside the acceptable tolerance. Commonly on the *x*-axis, each small square was thought to be 0.1 rather than 0.05. Often the log(Mn^{2+}) value of –0.30 was mis-plotted as –3.0, such a plot being well away from the rest of the plotted data. In such situations, candidates should be encouraged to examine such plots to reveal possible plotting errors. Sometimes points were omitted, or the line did not cover all the plotted points.

(d) (i) Most candidates correctly identified the point at –2.22, –1.250 as anomalous. In the case of plotting errors, the most deviant point was accepted. Some candidates circled more than one point or a point on the line.

(ii) A range of reasons were offered here. Many candidates suggested that mistakes were made in mis-reading the voltmeter or gave answers such as 'the concentration was wrong', which whilst not incorrect, are not specific enough. Candidates could work out from their line an interpolated value of *E* for a concentration of 6.00×10^{-3} mol dm^{-3}. The recorded value of –1.250 V is more negative than that interpolated value of *E* from the line. The data in the table demonstrates that as concentration decreases, *E* becomes more negative. Therefore, the concentration made up (giving an *E* = –1.250 V) was less than 6.00×10^{-3} mol dm^{-3}, so the solution was too dilute.

(e) A considerable number of candidates did not seem to realise the Nernst equation is of the form $y = mx + c$. Thus, many candidates tried solving the equation using table values for log(Mn^{z+}) and E and with an assumed value of 2 for z. Such a calculation was not using the graph as requested. The correct approach using the value of intercept on the *y*-axis (for log(Mn^{z+}) = 0 was much simpler. Unfortunately, some candidates with a correct value missed the negative sign.

(f) (i) Most candidates gave two correct co-ordinates for points on the line. Generally, candidates stated table points that were on the line. Others stated table points that were not on their line. A limited number of candidates did not present the co-ordinates in the correct *x*,*y* format. A general condition for gradient calculation is that there must be sufficient range in the values of the co-ordinates to validate the gradient. Usually, the range taken is at least half of an axis, in this case the difference in the y values needed to be $\geq 0.06\,V$, which a significant number of candidates did not have.

The gradient calculations were often well done, with only a few candidates reversing *x* and *y* values. It was more common to not present the gradient to three significant figures. Typically, a gradient value of 0.0293 was given as 0.029 (three decimal places rather than three significant figures) or 0.03, as a result of unwarranted rounding.

(ii) A keystone of this question was the requirement to use the value found in **f(i)** to calculate a value for z. This was further emphasised by the provision of a rescue value of 0.0197. Many did not correctly do this, instead using a calculation of the Nernst equation using table values for log(Mn^{z+}) and E and an $E^{\ominus}$ value from **(e)**. Unfortunately, a ratio of log(Mn^{2+}): E is not equal to the gradient so the gradient cannot be used directly in the Nernst equation. Instead, and much simpler, the gradient is equal to 0.059/z (directly from the Nernst equation) from which it is simple to calculate a value for z. This needed to be stated to three significant figures (e.g. 2.01) as it is the result of a calculation.

Many candidates gave 2 as the value for z, presumably applying chemical knowledge to an answer that did not require it at that stage. Some had a formula of $Mn^{1.97+}$ for the manganese ion from a value of 1.97 for z.

(g) Generally, this was not answered well. To make progress in this question, candidates needed to realise that there was a reversible reaction in the manganese cell that would achieve equilibrium. Some who did, suggested that the position of the equilibrium would move to the left or the right or forwards or backwards, but without defining the reversible reaction making such answers meaningless. Better performing candidates stated that the position of the equilibrium shifts to produce more Mn^{2+} (oxidation, electrons) in accordance with le Chatelier's principle.

Question 2

(a) (i) The majority of candidates were successful in this stoichiometric calculation. Some candidates misunderstood the meaning of 3 preceding the propan-2-ol and presented the M_r of propan-2-ol as 180 (i.e. 3 × 60). Others missed its significance, so had an incorrect stoichiometric ratio. Common errors included an incorrect M_r, unnecessary approximations or truncations.

(ii) Attempts at this simple distillation diagram were mostly very poor, possibly indicating that more direct experimental chemistry experience would be beneficial. In particular, the variety of coolants in the condenser (cold glass beads, ice etc.) indicate a lack of familiarity with condensers. Most candidates did not include a thermometer and of those that did rarely had it in the correct place (opposite the side arm of the still head). Many attempted to include a condenser, but most did not show a physical separation of cooling water from the condensing vapour. Often the connection at the top of the round-bottomed flask was open to the air so would not function. At the other end, the output of the condenser was often sealed into the collection flask, so again would not function. The inclusion of extra unnecessary items such as reflux condensers, fractionating columns, Bunsen burners was common. However, most candidates correctly placed the propanone in the collection flask but were not so successful in placing the propan-2-ol.

(iii) Candidates needed to link the flammability of propan-2-ol (given in the question data) or of propanone with avoiding using a naked flame in some form or other. Some candidates had 'avoid heat', which is not the same as a naked flame, as the reaction did need heating. A popular answer, which was not worthy of credit, was that a water bath would provide a constant or controllable temperature.

(iv) This question highlighted the need in candidates for simple chemical reaction knowledge. A reactant that reacts with the acidic character of sulfuric acid in such a way that the removal of acidity can be determined, was required. A number of candidates chose to use a barium(II) compound to precipitate barium sulfate. This was unsuitable as it just removes sulfate ion from solution not the H^+ ion as required by the question. Furthermore, in these cases the candidates had that the completion of the reaction could be determined by the lack of further precipitation – this is impossible to see in a solution that already contains a precipitate. An acceptable barium(II) compound was barium(II) hydroxide but this was usually paired with sulfate precipitation rather than removal of acidity. Any reagent that would react with acid was acceptable. This would include any metal oxide or hydroxide, any metal carbonate or hydrogen carbonate or any suitable metal i.e. not one that reacts with water or a metal that does not react with sulfuric acid. Some candidates incorrectly stated potassium manganate(VII), potassium dichromate(VI), nitric acid or hydrochloric acid.

Many incomplete explanations were seen. There needs to be a stated definite observation that follows on from the total reaction of the acid. Answers such as, 'add sodium hydroxide until no more sodium sulfate is formed' show a lack of basic chemistry. With a carbonate, hydrogen carbonate or a metal, an observation of 'no further effervescence' cannot be taken as meaning all the acid has reacted, as the opposite alternative of 'all of the added reagent has been used up' is equally invalid. Additions of gas producing reagents, needed to be qualified with 'excess' or 'added until there was no further effervescence'. A similar situation pertains to additions of insoluble bases such as copper(II) oxide or metals where there must be an observation of unreacted reagent to ensure all of the acid had reacted. In the case of alkalis, the use of a pH meter or indicator alone was common but insufficient. It was necessary to include an observation from the meter or indicator to show that all of the acid had reacted.

(b) (i) The question was a straightforward comparison of two different filtration techniques, thus a comparative response was required. Responses such as, 'in technique **B** the precipitate was dry' were not creditworthy. Other responses in terms of efficiency (difficult to quantify) or purity (not correct) also gained no credit. Only correct comparative observations such as 'faster' or 'drier' were accepted.

(ii) Heating to a constant mass is a standard procedure and many candidates explained the procedure quite well. To be correct, the answer needed to include a repetition of drying in the oven and weighing to a constant mass. Some candidates omitted one or other of these. Many candidates suggested using drying agents (e.g. anhydrous copper(II) sulfate) and tests (cobalt chloride paper).

(iii) This three-part calculation was done reasonably well. Most candidates had the correct method either by way of mass or moles of propanone and **X**. Many candidates rounded within their calculations, which caused increasing deviation from the result. Such approximations are unnecessary and often lead to incorrect answers.

(iv) The most probable cause of sub 100% yield was that, in common with most organic reactions, the reaction is reversible so does not go to completion. Also allowed were some **X** may remain in solution or is stuck in the filter.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates could not provide suitable details of apparatus needed in **Question 1(a)(iii)** and the required measurements in **Question 1(e)(ii)** were not known.

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

Candidates should be dissuaded from offering lists of answers beyond the number of responses asked for. **Question (2)(d)(iii)** required one piece of apparatus and correct answers were often contradicted by inclusion of other, unsuitable, pieces of apparatus.

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

General comments

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

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

Comments on specific questions

Question 1

(a) (i) The opening question was well answered but poor examination technique was evident, especially for the dependent variable. Most realised that it was the *volume* of gas/carbon dioxide, but often said ‘amount of gas’ or even simply ‘carbon dioxide’, neither of which was enough to be awarded credit. The independent variable was the type of metal ore, although this could be expressed in a variety of ways. However, the mass of the metal ore was not the independent variable.

(ii) Many candidates opted to keep the concentration (or even volume) of the acid constant, presumably on the false premise that this was a rate of reaction investigation. Very few realised that the temperature of the collected carbon dioxide needed to be kept constant. Others opted for temperature of the reaction mixture (based upon the idea of a rate experiment).

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

Candidates were faced with three problems.

The first problem was to enable mixing of ore and acid without loss of gas. Better responses used the idea of a small vessel containing ore suspended by string within a sealed flask containing acid. Divided flasks were also seen in responses. In most incorrect responses, candidates simply had the acid and carbonate reacting in a flask, and in the absence of other details, it was therefore assumed that the first few bubbles of carbon dioxide would escape to the atmosphere.

The final problem was collection over water. Most of the candidates opted for an inverted measuring cylinder, but an inverted burette would have been acceptable. However, a large proportion of candidates did not appreciate that collection over water was required and opted for a gas syringe, sometimes connected the syringe after the gas was bubbled through water.

The intermediate problem was to get the gas from the reaction vessel into a collection vessel in sealed apparatus. This was by far the easiest step. Inaccurate diagrams were often seen, with delivery tubes entering through the side of measuring cylinders were not accepted.

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

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

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

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

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

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

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

Question 2

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

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

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

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

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

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

(e) (i) The points were plotted correctly by most candidates. A minority omitted the plot at the origin. Many good ruler lines of best fit were drawn.

(ii) The relationship of direct proportionality was identified by nearly all candidates.

(f) (i) Nearly all candidates were able to take a value from the graph correctly, although the different scales on each axis meant 0.18 was given instead of 0.19.

(ii) The final calculation was more challenging than the previous ones, but most candidates still achieved full credit. Common errors included opting for an incorrect volume of copper solution or rounding too soon in the calculation.

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Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- Better performing candidates gave numerical answers to the required number of decimal places or significant figures, as required by the questions.
- Some candidates need to improve of the legibility of their answers.
- Candidates should set out calculations in a logical sequence, which enables credit for error carried forward to be applied where necessary.

General comments

There was a tendency to over approximate, truncate and incorrectly round, particularly approximating within a calculation. Such approximation usually leads to increasing divergence of result and is particularly significant in multistage calculations as in **Question 2(b)(iii)**. Candidates should be advised to carry through values held on their calculators, thus avoiding approximating divergence.

The numerical questions, **Questions 1(b)(i)**, **2(a)(i)** and **2(b)(iii)** were answered better than the textual chemical questions.

There was evidence of a lack of basic chemical knowledge from some candidates. This was displayed in, for example, **Question 2(a)(i)** where the '3' in the equation in front of the propan-2-ol was included in the M_r, as well as in the stoichiometric calculation. This was also seen in **Question 2(a)(iv)**, where unsuitable reagents such as lithium tetrahydroborate or silver nitrate were proposed. Poor diagrams were seen in **Question 2(a)(ii)**. This suggests that some candidates would benefit from a greater exposure to apparatus, chemicals and their reactions through realistic laboratory work.

Some inconsistent answers were seen where a moment's reflection on the candidates' part may have exposed their error. Thus in **Question 1(b)(i)**, a popular incorrect answer of using 250 cm^3 of manganese(II) solution to prepare (as in the question) a 100 cm^3 final solution.

There was a tendency to over-answer, perhaps in the hope of something being correct. This approach is to be avoided, as numerous answers often contradict each other. In **Question 2(b)(i)**, an answer such as 'filtration would be faster, more efficient and would give a dry sample of **X**' contains a correct and an incorrect response. Contradictory answers were also common in **Questions 1(d)(ii)**, **1(g)**, **2(a)(ii)** and **2(b)(iv)**. As such, candidates should avoid over-answering in order to minimise the introduction of contradictions.

Candidates should be discouraged from giving non-specific responses. For example, as in **Question 2(b)(ii)** 'heat it and measure the change'; in **Question 1(d)(ii)** 'the concentration was incorrectly prepared resulting in a higher or lower actual concentration' which has no effective meaning. Other statements such as, 'the temperature was wrong' or 'the candidate had an incorrect concentration' also have no real meaning.

Comments on specific questions

Question 1

(a) The requirement for three answers was usually satisfied and over half of the candidates did well. A few candidates labelled the voltmeter as an ammeter or power supply. The most common error was to incorrectly label the copper(II) concentration as 0.500 mol dm^{-3}, presumably taking a lead from the concentration of manganese(II), whereas the question stated the copper(II)/copper half-cell as a standard half-cell, which would feature 1.000 mol dm^{-3} solutions.

(b) (i) This standard, dilution question was correctly answered by most of the candidates. A popular incorrect response was 250 cm^3, which was at odds with the clear question requirement to produce a 100 cm^3 solution.

(ii) This question required a two-part answer. Firstly, accurately measuring a solution volume then secondly accurately diluting it – the emphasis being on accurate. The best way of measuring the volume from **(b)(i)** is by delivering it from a burette. Measuring cylinders are insufficiently accurate for this procedure. Pipettes could be used, provided they were of a size generally available, for example the use of a 20 cm^3 pipette twice. Pipettes with no stated volume were not accepted nor were 40 cm^3 pipettes. After delivering the solution from the burette, some candidates erroneously rinsed the burette with water, which was added to the original delivery. Some contradictory answers appeared here, such as 'use a burette or a measuring cylinder'.

A significant number of candidates confused this procedure with that for making a solution from a solid so did not deliver their volume into the 100 cm^3 volumetric flask. These candidates chose a beaker or flask into which they added some water, stirred then transferred to the volumetric flask. This unnecessary procedure was accepted provided distilled water was used, the beaker was washed with distilled water and the washings added to the volumetric flask, and the volume did not exceed 100 cm^3.

The dilution to 100 cm^3 in the volumetric flask was done better. However, many candidates did not specify distilled water. Some erroneously added 60 cm^3, often by measuring cylinder and others had 'make to 100 cm^3' without stating that the only way this could be done was by making to the mark in a volumetric flask.

(iii) The table had simple calculations, including correctly quoting to either two or three decimal places, at which virtually all candidates succeeded. Three values of log(Mn^{2+}) were often truncated rather than correctly rounded. For example, the calculator value from the second table concentration was –0.6989700043, which was typically truncated to –0.69 rather than correctly rounded to –0.70. The other common error was to omit the last digit if it was zero, for example –1.210 was given as –1.21.

(c) The plotting of the data was generally very well done, as was the line. Most mis-plots were quite close to being correct but outside the acceptable tolerance. Commonly on the *x*-axis, each small square was thought to be 0.1 rather than 0.05. Often the log(Mn^{2+}) value of –0.30 was mis-plotted as –3.0, such a plot being well away from the rest of the plotted data. In such situations, candidates should be encouraged to examine such plots to reveal possible plotting errors. Sometimes points were omitted, or the line did not cover all the plotted points.

(d) (i) Most candidates correctly identified the point at –2.22, –1.250 as anomalous. In the case of plotting errors, the most deviant point was accepted. Some candidates circled more than one point or a point on the line.

(ii) A range of reasons were offered here. Many candidates suggested that mistakes were made in mis-reading the voltmeter or gave answers such as 'the concentration was wrong', which whilst not incorrect, are not specific enough. Candidates could work out from their line an interpolated value of *E* for a concentration of 6.00×10^{-3} mol dm^{-3}. The recorded value of –1.250 V is more negative than that interpolated value of *E* from the line. The data in the table demonstrates that as concentration decreases, *E* becomes more negative. Therefore, the concentration made up (giving an *E* = –1.250 V) was less than 6.00×10^{-3} mol dm^{-3}, so the solution was too dilute.

(e) A considerable number of candidates did not seem to realise the Nernst equation is of the form $y = mx + c$. Thus, many candidates tried solving the equation using table values for $\log(Mn^{z+})$ and *E* and with an assumed value of 2 for z. Such a calculation was not using the graph as requested. The correct approach using the value of intercept on the *y*-axis (for $\log(Mn^{z+}) = 0$ was much simpler. Unfortunately, some candidates with a correct value missed the negative sign.

(f) (i) Most candidates gave two correct co-ordinates for points on the line. Generally, candidates stated table points that were on the line. Others stated table points that were not on their line. A limited number of candidates did not present the co-ordinates in the correct *x*,*y* format. A general condition for gradient calculation is that there must be sufficient range in the values of the co-ordinates to validate the gradient. Usually, the range taken is at least half of an axis, in this case the difference in the y values needed to be $\geq 0.06\,V$, which a significant number of candidates did not have.

The gradient calculations were often well done, with only a few candidates reversing *x* and *y* values. It was more common to not present the gradient to three significant figures. Typically, a gradient value of 0.0293 was given as 0.029 (three decimal places rather than three significant figures) or 0.03, as a result of unwarranted rounding.

(ii) A keystone of this question was the requirement to use the value found in **f(i)** to calculate a value for z. This was further emphasised by the provision of a rescue value of 0.0197. Many did not correctly do this, instead using a calculation of the Nernst equation using table values for $\log(Mn^{z+})$ and *E* and an $E^{\ominus}$ value from **(e)**. Unfortunately, a ratio of $\log(Mn^{2+})$: *E* is not equal to the gradient so the gradient cannot be used directly in the Nernst equation. Instead, and much simpler, the gradient is equal to 0.059/z (directly from the Nernst equation) from which it is simple to calculate a value for z. This needed to be stated to three significant figures (e.g. 2.01) as it is the result of a calculation.

Many candidates gave 2 as the value for z, presumably applying chemical knowledge to an answer that did not require it at that stage. Some had a formula of $Mn^{1.97+}$ for the manganese ion from a value of 1.97 for z.

(g) Generally, this was not answered well. To make progress in this question, candidates needed to realise that there was a reversible reaction in the manganese cell that would achieve equilibrium. Some who did, suggested that the position of the equilibrium would move to the left or the right or forwards or backwards, but without defining the reversible reaction making such answers meaningless. Better performing candidates stated that the position of the equilibrium shifts to produce more Mn^{2+} (oxidation, electrons) in accordance with le Chatelier's principle.

Question 2

(a) (i) The majority of candidates were successful in this stoichiometric calculation. Some candidates misunderstood the meaning of 3 preceding the propan-2-ol and presented the M_r of propan-2-ol as 180 (i.e. 3 × 60). Others missed its significance, so had an incorrect stoichiometric ratio. Common errors included an incorrect M_r, unnecessary approximations or truncations.

(ii) Attempts at this simple distillation diagram were mostly very poor, possibly indicating that more direct experimental chemistry experience would be beneficial. In particular, the variety of coolants in the condenser (cold glass beads, ice etc.) indicate a lack of familiarity with condensers. Most candidates did not include a thermometer and of those that did rarely had it in the correct place (opposite the side arm of the still head). Many attempted to include a condenser, but most did not show a physical separation of cooling water from the condensing vapour. Often the connection at the top of the round-bottomed flask was open to the air so would not function. At the other end, the output of the condenser was often sealed into the collection flask, so again would not function. The inclusion of extra unnecessary items such as reflux condensers, fractionating columns, Bunsen burners was common. However, most candidates correctly placed the propanone in the collection flask but were not so successful in placing the propan-2-ol.

(iii) Candidates needed to link the flammability of propan-2-ol (given in the question data) or of propanone with avoiding using a naked flame in some form or other. Some candidates had 'avoid heat', which is not the same as a naked flame, as the reaction did need heating. A popular answer, which was not worthy of credit, was that a water bath would provide a constant or controllable temperature.

(iv) This question highlighted the need in candidates for simple chemical reaction knowledge. A reactant that reacts with the acidic character of sulfuric acid in such a way that the removal of acidity can be determined, was required. A number of candidates chose to use a barium(II) compound to precipitate barium sulfate. This was unsuitable as it just removes sulfate ion from solution not the H^+ ion as required by the question. Furthermore, in these cases the candidates had that the completion of the reaction could be determined by the lack of further precipitation – this is impossible to see in a solution that already contains a precipitate. An acceptable barium(II) compound was barium(II) hydroxide but this was usually paired with sulfate precipitation rather than removal of acidity. Any reagent that would react with acid was acceptable. This would include any metal oxide or hydroxide, any metal carbonate or hydrogen carbonate or any suitable metal i.e. not one that reacts with water or a metal that does not react with sulfuric acid. Some candidates incorrectly stated potassium manganate(VII), potassium dichromate(VI), nitric acid or hydrochloric acid.

Many incomplete explanations were seen. There needs to be a stated definite observation that follows on from the total reaction of the acid. Answers such as, ‘add sodium hydroxide until no more sodium sulfate is formed’ show a lack of basic chemistry. With a carbonate, hydrogen carbonate or a metal, an observation of ‘no further effervescence’ cannot be taken as meaning all the acid has reacted, as the opposite alternative of ‘all of the added reagent has been used up’ is equally invalid. Additions of gas producing reagents, needed to be qualified with ‘excess’ or ‘added until there was no further effervescence’. A similar situation pertains to additions of insoluble bases such as copper(II) oxide or metals where there must be an observation of unreacted reagent to ensure all of the acid had reacted. In the case of alkalis, the use of a pH meter or indicator alone was common but insufficient. It was necessary to include an observation from the meter or indicator to show that all of the acid had reacted.

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