CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Questions 1, **2**, **6**, **9**, **10**, **11**, **17**, **19**, **22**, **26**, **28** and **32** were found to be easier.

Questions 13, **29**, **33**, **34** and **39** were found to be particularly difficult. These questions will be looked at in greater detail.

Comments on specific questions

Question 13

The most common chosen incorrect answer was option **A**. The pH values indicate that this is a strong acid/strong alkali titration therefore **B** and **D** can be ruled out. The acid and alkali are stated as having the same concentration. The titration curve shows that 20 cm^3 of P is neutralised by 10 cm^3 of Q, therefore the stoichiometry in the equation is 2P:1Q. The correct answer is therefore option **C** since
$2HCl + Ba(OH)_2 \rightarrow BaCl_2 + 2H_2O$.

Question 29

The most common chosen incorrect answer was option **D**. The correct answer cannot be **D** since NO_2 is removed by reduction in a catalytic converter, not by oxidation. Unburnt hydrocarbons are oxidised in a catalytic converter to carbon dioxide and water. Carbon monoxide is oxidised in a catalytic converter to carbon dioxide. Statements 1 and 3 only are true. The correct answer is option **C**

Question 33

The incorrect options, **B**, **C** and **D**, were all chosen equally by candidates.

Compound A has:
- two aldehyde groups, each of which is oxidised by one atom of oxygen to form a carboxylic acid group
- one secondary alcohol group, which is oxidised by one atom of oxygen to form a ketone and a water molecule.

Altogether three oxygen atoms are needed, and one water molecule is produced.

Compound B has:
- three primary alcohol groups, each of which is oxidised by two atoms of oxygen to form a carboxylic acid group and a water molecule. Six oxygen atoms are needed.

Compound C has:
- two primary alcohol groups and one secondary alcohol group. Five oxygen atoms are needed.

Compound D has:
- three aldehyde groups. Three oxygen atoms are needed but no water molecule is produced.

Question 34

The most common chosen incorrect answer was option **C**. When propan-1-ol reacts with sodium the product, $CH_3CH_2CH_2O^-Na^+$, is called sodium propoxide. The formula of sodium propanoate is $CH_3CH_2CO_2^-Na^+$. The correct answer is option **D**.

Question 39

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

Compounds 1 and 3 both have the molecular formula $C_6H_{14}O$. The equation for their complete combustion is $C_6H_{13}OH + 9O_2 \rightarrow 6CO_2 + 7H_2O$.Neither compound fits the statement in the first bullet point.

Compounds 2 and 4 both have the molecular formula $C_6H_{12}O$. The equation for their complete combustion is $C_6H_{11}OH + 8½O_2 \rightarrow 6CO_2 + 6H_2O$. Both compounds fit the statement in the first bullet point.

Compound 2 is a tertiary alcohol and compound 4 is a ketone. Both compounds fit the statement in the second bullet point. The correct answer is option **B**.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

Questions 2, **8**, **9**, **11**, **13**, **19**, **27**, **28**, **30** and **40** were found to be easier

Questions 5, **16**, **21**, **22** and **38** were found to be particularly difficult. These questions will be looked at in greater detail.

Comments on specific questions

Question 5

The most common chosen incorrect answer was option **C**. Hybridisation does not change the total number of orbitals present. Here, one s orbital and three p orbitals result in two sp hybrid orbitals and two unchanged p orbitals. These p orbitals overlap, two from one nitrogen atom and two from the other, producing the two π bonds between the nitrogen atoms. That means that the σ bond and the lone pair on each nitrogen atom result from the sp hybrid orbitals. The correct answer is option **B**.

Question 16

The most common chosen incorrect answer was option **C**. Candidates knew that NO and NO_2 are involved in the formation of photochemical smog and that NO_2 is involved in the formation of acid rain. Candidates were unsure of the involvement of NO in the formation of acid rain. NO reacts with oxygen in the atmosphere to produce NO_2. This means that NO in the atmosphere results in increased levels of NO_2 in the atmosphere. NO is therefore involved in the formation of acid rain. The correct answer is option **A**.

Question 21

The most common chosen incorrect answer was option **C**. In the balanced equation three moles of chlorine produce five moles of NaC*l* and one mole of NaC*l*O_3. This means 0.600 mol of chlorine produces 0.200 mol of NaC*l*O_3.

$0.200 \times (23 + 35.5 + 48) = 21.3$

The correct answer is option **A**. The choice of **C** suggests that some candidates believed that one mole of chlorine produces one mole of NaC*l*O_3.

Question 22

The most common chosen incorrect answer was option **B**. X reacts with concentrated H_2SO_4 to produce H_2S, this means X can only be sodium iodide. Y does not reduce concentrated H_2SO_4, this means Y can only be sodium chloride. Statement **A** is correct – aqueous sodium iodide does reduce aqueous bromine, producing iodine and sodium bromide. Statement **C** cannot be correct – if sodium chloride reacted with concentrated H_2SO_4 to produce chlorine this would mean that the concentrated H_2SO_4 would be reduced in this reaction. This is not correct.

Question 38

The most common chosen incorrect answer was option **B**. One mole of butanenitrile, C_3H_7CN, reacts with two moles of hydrogen to produce one mole of butylamine, $C_4H_9NH_2$. 0.500 g of butanenitrile contains 0.00725 moles, this reacts with 0.0145 moles of hydrogen. This occupies 348 cm^3 at room conditions, option **D**. Candidates who chose **B**, 174 cm^3, possibly believed that one mole of butanenitrile, C_3H_7CN, reacts with one mole of hydrogen.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General comments

Questions 1, **2**, **6**, **9**, **10**, **11**, **17**, **19**, **22**, **26**, **28** and **32** were found to be easier.

Questions 13, **29**, **33**, **34** and **39** were found to be particularly difficult. These questions will be looked at in greater detail.

Comments on specific questions

Question 13

The most common chosen incorrect answer was option **A**. The pH values indicate that this is a strong acid/strong alkali titration therefore **B** and **D** can be ruled out. The acid and alkali are stated as having the same concentration. The titration curve shows that 20 cm^3 of P is neutralised by 10 cm^3 of Q, therefore the stoichiometry in the equation is 2P:1Q. The correct answer is therefore option **C** since
$2HCl + Ba(OH)_2 \rightarrow BaCl_2 + 2H_2O$.

Question 29

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Question 33

The incorrect options, **B**, **C** and **D**, were all chosen equally by candidates.

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- three aldehyde groups. Three oxygen atoms are needed but no water molecule is produced.

Question 34

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Question 39

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Compounds 2 and 4 both have the molecular formula $C_6H_{12}O$. The equation for their complete combustion is $C_6H_{11}OH + 8½O_2 \rightarrow 6CO_2 + 6H_2O$. Both compounds fit the statement in the first bullet point.

Compound 2 is a tertiary alcohol and compound 4 is a ketone. Both compounds fit the statement in the second bullet point. The correct answer is option **B**.

CHEMISTRY

Paper 9701/14
Multiple Choice

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

General comments

Questions 1, **2**, **6**, **7**, **9**, **12**, **15**, **18**, **28**, **36**, **39**, and **40** were found to be easier.

Questions 3, **5**, **25**, **30** and **37** were found to be particularly difficult. These questions will be looked at in greater detail.

Comments on specific questions

Question 3

The most common chosen incorrect answer was option **A**. 10 cm^3 of methanethiol gas reacts with 30 cm^3 of oxygen. There is 30 cm^3 of unreacted oxygen remaining. The products include 10 cm^3 of CO_2 and 10 cm^3 of SO_2. This makes the final volume of the resultant mixture of gases equal to 50 cm^3, option **C**

Question 5

The most common chosen incorrect answer was option **C**.

- Options **A** and **B** both include a group 15 hydride. These molecules have a lone pair of electrons so neither is planar.
- Option **C** includes C_3H_6. C_3H_6 could be propene, which has a methyl group and so is not planar. C_3H_6 could be cyclopropane, the geometry around each carbon atom is approximately tetrahedral, so the molecule is not planar.
- Option **D** is the correct answer. Ethene, carbon dioxide and water all have their atoms arranged in one plane.

Question 25

. The most common chosen incorrect answer was option **B**.

- $CH_3CHC(CH_3)CH_3$ is an alkene with a C=C double bond. This means that it can also undergo electrophilic addition, so the correct answer can only be option **A** or **B**.
- $CH_3CHC(CH_3)CH_3$ is an alkene it is unsaturated. $CH_3CH(CH_3)CH_2CH_3$ is an alkane and so it is a saturated hydrocarbon. The correct answer is therefore option **A**.

Question 30

. The most common chosen incorrect answer was option **C**.

- The key information in the question is that the reaction between NaOH(aq) and 1-bromobutane proceeds by an S_N2 mechanism. The first step involves attack by a nucleophile, OH^-, on a $C^{\delta+}$ atom. The correct answer is option **A**.
- Choice **C** is only correct for a reaction that proceeds by an S_N1 mechanism, such as the reaction between NaOH(aq) and 2-bromomethylpropane.

Question 37

. The most common chosen incorrect answer was option **C**.

- Aldehydes are not oxidised by dilute hydrochloric acid. Compound 1, ethanal, will not produce ethanoic acid.
- Nitriles are hydrolysed by dilute hydrochloric acid. Compound 2, ethanenitrile, will produce ethanoic acid.
- Esters are hydrolysed by dilute hydrochloric acid. Compound 3, methyl ethanoate, will produce methanol and ethanoic acid. The correct compounds are 2 and 3 only, so the correct answer is option **D**.

CHEMISTRY

Paper 9701/21
AS Level Structured Questions

Key messages

Candidates are advised to learn definitions precisely.

Candidates regularly missed out key words or key phrases when writing definitions in this paper.

General comments

Candidates struggled with the concept of intermolecular forces of attraction and their application to physical states and boiling/melting points. For example, **Question 1c(iv)**, statements describing why compounds exist in different physical states, at a specific temperature, often included the breaking of unspecified bonds.

The idea that 'forces of attraction exist between molecules' does require emphasising, for the different types of intermolecular attractions.

Enthalpy calculations requiring more than one step were poorly answered and only the stronger candidates performed well.

Stronger candidates performed well in **Question 4c** using a mass spectrum to identify an organic compound. More practice on the use of spectroscopy to identify compounds would be beneficial.

Comments on specific questions

Question 1

(a) (i) The number of protons, neutrons and electrons in an atom of the isotope chromium-52, was commonly correctly answered as 24, 28 and 24 respectively.

(ii) The difference between an atom of chromium-54 and chromium-52 was recognised as two neutrons by most candidates.

(iii) The information required, from a mass spectrum, to determine the relative atomic mass, A_r, of Cr, is the relative abundance of each isotope. There were many correct answers. Common errors included mention of unified atomic mass, moles or atomic mass.

(iv) Many candidates correctly stated that the fourth isotope of chromium had a relative isotopic mass of less than 52. Several candidates mentioned that the fourth isotope had the smallest % abundance but then did not refer to its relative isotopic mass.

(b) (i) The full electronic configuration of chromium was well known.

(ii) This question was well answered.

(c) (i) Candidates often identified Cr as the reduced species in the given half equation involving acidified $Cr_2O_7^{2-}$ and Cr^{3+}, but explanations using oxidation numbers were frequently incorrect with the numbers regularly reduced from 7 to 3 or 12 to 3.

Answers that avoided the use of oxidation numbers and stated that the Cr had gained electrons, were often correct. Other common errors stated that H^+ was reduced or that oxygen was lost.

(ii) This question was well answered.

(iii) Due to an issue with **Question 1(c)(iii)**, full marks have been awarded to all candidates for this question to ensure that no candidates were disadvantaged.

(iv) Methanal is a liquid at –30 °C because it has permanent dipole-permanent dipole forces of attraction between its molecules compared to the weaker instantaneous dipole-induced dipole intermolecular forces of attraction between gaseous CO_2 molecules.

This question proved difficult for many candidates as many stated that bonds are broken on melting. Several candidates compared the strength of bonds in methanal with those in CO_2. A common error was that hydrogen bonds were present in methanal.

(d) (i) The definition of 'dynamic equilibrium' was well answered.

(ii) The condition necessary to establish equilibrium is a 'closed system'. Many incorrect answers stated that a 'constant temperature or constant pressure was required'.

(iii) Many candidates recognised that the equilibrium, given in the question, between CrO_4^{2-}(aq) and $Cr_2O_7^{2-}$(aq), under acidic conditions, was an endothermic reaction. Candidates often gave a correct observation of the colour and position of the equilibrium mixture, when warmed.

When HC*l* (aq) was separately added to the equilibrium mixture, few candidates appreciated that the change, to an orange colour, was a result of the equilibrium shifting right to compensate for the added H^+(aq) ions.

(e) Many candidates correctly stated that the reaction between CrF_4 and water is a hydrolysis reaction. The equation for this reaction was less well known. Common errors included the introduction of $SiCl_4$ or SiF_4 into the equation.

Question 2

(a) (i) Many good answers were seen for the trend in atomic radii of the Period 3 elements.

(ii) Many answers gained partial credit for correctly stating that the large difference in ionic radii between A*l* and P is due, in part, to the A*l* losing its 3 valence electrons and P gaining 3 electrons, in its valence shell. Few candidates then qualified this with a creditworthy statement that the consequence is that Al then lost an outer shell whilst P retained its outer shell.

(b) (i) Most candidates were able to correctly complete the oxidation numbers of Period 3 elements, in their oxides. The pH of solutions of the Period 3 oxides was less well known with the most common' error being incorrect values for the pH of solutions of Na_2O and MgO.

(ii) Many candidates correctly stated that data for the pH of solutions of Al_2O_3 and SiO_2 was not given in the Table because these two oxides are insoluble. Frequent errors stated that these oxides were amphoteric or did not react with water.

(c) (i) The equation for the reaction between Na_2O and dilute hydrochloric acid was well answered.

(ii) Most candidates gave correct answers for the equation of the reaction between Al_2O_3 and a base to form $NaAlO_2$.

(d) (i) Candidates performed well in this question which required a statement on the trend in thermal stability of Group 2 nitrates down the group.

(ii) Apart from the metal oxide, the products from the thermal decomposition of Group 2 nitrates, are NO_2 and O_2.

A significant number of answers either omitted O_2 or gave N_2 and even CO_2 as incorrect answers.

Question 3

(a) The definition of 'empirical formula' was generally poorly answered. The main errors included the use of statements as:

- simplest molecular formula
- simplest ratio in a formula
- the simplest ratio atoms or simplest ratio of the elements (instead of simplest ratio of each atom of the elements in a compound).

(b) Many candidates correctly identified one of the two required cyclic structural isomers of cyclopentane, but the second isomer was often an incorrect rearrangement of the same isomer given in the question.

(c) (i) The type of bond fission of Cl_2, in the reaction using ultraviolet light, is homolytic fission. Common errors included the use of heterolytic and homologous fission.

(ii) The completion of the given partial equations for the two propagation steps between C_5H_{10} and Cl_2 was well answered. Common errors included the use of Cl_2 in propagation step 1 and a termination reaction in step 2.

(iii) Most candidates recognised that the equation, given in the question, representing the final step in the reaction, was a termination reaction.

(d) (i) The reagent for the formation of chlorocyclopentane from cyclopentene is gaseous hydrogen chloride. Many candidates incorrectly quoted hydrochloric acid.

(ii) Many candidates found this question challenging. The enthalpy change required in the question, ΔH_2, could be evaluated by first calculating the enthalpy change for reaction 1, and then using this value, together with ΔH_3, to complete the calculation.

Several candidates did not use all the data in Table 3.1, to calculate the enthalpy term for reaction 1, and candidates who did attempt to calculate an enthalpy term, often did not then use it correctly to evaluate ΔH_2.

(e) (i) Many correct answers were seen for the oxidative cleavage of cyclopentene to form pentanedioic acid. The most common errors were cyclic structures with no ring cleavage.

(ii) Most candidates gave correct answers showing clearly defined C=O and O−H bonds, for the absorptions, and correct labels on the infrared spectrum of the dicarboxylic acid (in **Question 3(e(i)**).

Question 4

(a) (i) The reduction of a carboxylic acid to a primary alcohol was recognised by many candidates as a reduction reaction. The most common errors described the reaction as an oxidation or dehydration reaction.

(ii) A suitable reagent for the conversion of an alcohol to a halogenoalkane can be $SOCl_2$, PCl_5, PCl_3, HCl(g) or the use of KCl and concentrated H_2SO_4 to generate HCl (g), in situ. Many candidates incorrectly quoted HCl as a suitable reagent without any qualifying state symbol.

(iii) Many candidates did not gain full credit because of incorrect equations or incorrect solvent and conditions. A common error in the equation was omitting either NaOH as a reactant or H_2O as a product. The condition of heat was often not included in answers and the ethanol solvent or the NaOH were sometimes stated as being in aqueous solution.

(iv) Many candidates correctly gave concentrated H_2SO_4 or Al_2O_3 and heat, as suitable reagents to convert an alcohol into an alkene. The most common errors were the omission of 'concentrated' for the acid and occasionally the inclusion of a mixture of the concentrated acid and Al_2O_3 and heat.

(b) (i) Addition is the only answer for describing the polymerisation of propene. This was correctly stated by many candidates.

(ii) The definition of stereoisomerism was often partially correct. Many candidates gained partial credit by stating that it was 'molecules with the same structural formula'. The inclusion of a statement explaining that the atoms or groups to have a different spatial arrangement was often not given. The most common errors were the omission of either a '3D arrangement' or no mention of 'atoms/groups'.

(iii) The drawings of a section of poly(propene), showing two repeat units was often the only creditworthy response for this question. After drawing a correct repeat unit, many candidates did not recognise the chiral C atoms, which would exhibit optical isomerism, and assumed that the type of stereoisomerism for this polymer was geometric/cis-trans or a form of structural isomerism.

(iv) The answers to the difficulties associated with the disposal of poly(propene) were varied. Many candidates gained some credit for stating that these polymers were not biodegradable. Stronger candidates often gave fully correct answers. The most common errors include the use of terms such as 'forms greenhouse gases', 'forms PAN', and did not consider the disposal of the polymers which was required in the question.

(c) (i) The name of the branched chain alkene was well answered. The most common incorrect answers were: 2,3-methylbut-1-ene or 2,3-dimethylbutene.

(ii) Few candidates correctly identified the correct alkene. Candidates did not identify that peaks at m/e = 41 and m/e = 43 were fragments from one of the alkenes, and that these fragments required a positive charge.

(iii) Many candidates used the formula: $\mathrm{n} = \frac{100 \times \text{abundance of } [\mathrm{M+1}]^+ \text{ ion}}{1.1 \times \text{abundance of } [\mathrm{M}]^+ \text{ ion}}$ to calculate the relative abundance of the $[M+1]^+$ peak.

Candidates who performed well understood that n was 6 here, as both alkenes given, had the same molecular formula of C_6H_{12}, and then continued to correctly calculate the relative abundance.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions

Key messages

Candidates are expected to understand the meaning of vocabulary specific to the syllabus and use these terms appropriately.

A good knowledge of the key details specified in the learning outcomes is essential to answer exam questions, particularly those which involve an application of knowledge.

General comments

High performing candidates reproduced standard definitions and explanations concisely and applied appropriate knowledge to novel situations using the relevant details provided.

On some occasions key vocabulary was used inappropriately and contradictions were included within answers.

Comments on specific questions

Question 1

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

(ii) The definition of isotope was generally well known. Occasionally, inappropriate use of the terms 'compound' or 'molecule' instead of 'element' or 'atom' was seen.

(iii) Many candidates noted that the relative abundances of the isotopes were needed. It was common for answers to incorrectly use 'relative atomic mass' rather than the 'relative mass of the isotopes.'

(b) (i) This question was answered correctly by the most candidates.

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

(c) (i) Most responses correctly identified the reduced species, with an appropriate explanation in terms of gain of electrons or change in oxidation states.

(ii) There was no specific pattern given in answers that incorrectly deduced the oxidation state of carbon.

(iii) Due to an issue with **Question 1(c)(iii)**, full marks have been awarded to all candidates for this question to ensure that no candidates were disadvantaged.

Question 2

(a) (i) Many responses described the presence of delocalised electrons. A smaller proportion of these answers linked the movement of delocalised electrons to explain electrical conductivity.

(ii) It was common for candidates to describe the absence of delocalised electrons. More detailed answers described the lack of conductivity due to the absence of both mobile ions and delocalised

electrons. Responses that referenced the lack of movement of 'all the electrons' or 'all outer shell electrons' or 'lone pairs of electrons' did not gain credit.

(b) The best responses related the difference in melting points to the forces of attraction or bonds broken during the melting process. Common misconceptions included the presence of intermolecular forces in silicon and breaking covalent bonds in the other three non-metals. Some responses described the structure and bonding of these elements without relating this knowledge to the process of melting.

(c) The trend in oxidation number across the period was well known. Frequent errors included identification of the pH of NaCl to be more or less than 7, silicon tetrachloride as a giant structure, and sodium chloride and/or magnesium chloride with metallic bonds.

(d) (i) Correct species were often present in the equations, however, unbalanced equations were seen.

(ii) This equation was correctly described by the majority. Unbalanced equations were occasionally seen.

(e) (i) This question was answered well. It was common for weaker responses to state that the 'forward reaction equals backward reaction' without any reference to rate.

(ii) The majority of candidates correctly identified 'closed system'. Common incorrect responses quoted standard conditions.

(iii) Many answers focused on application of Le Chatelier's principle to explain the chemistry of the changes with no reference to relevant observations. Explanations in terms of the effect of an increase in temperature were well understood by the majority. The effect of the change in pressure was less well understood. Many answers considered the total number of moles of reactants and products, regardless of their states, to conclude that there is no change to the position of equilibrium.

(f) (i) This equation proved to be challenging. Equations that showed all the appropriate formulas were not always balanced. The formula of sodium chloride was sometimes described incorrectly as NaCl_2. The state symbols were sometimes omitted and NaCl(s) was a common error.

(ii) Some answers correctly described both products for this thermal decomposition. Weaker responses identified one. Common incorrect products included magnesium and carbon monoxide.

(iii) The trend in thermal stability was well known.

Question 3

(a) The most common answer was given in terms of a 'group of compounds with the same functional group and a similarity in their chemical properties or similar chemical reactions'. Weaker responses included contradictory statements. Confusion of the terms molecular formula, empirical formula and general formula was seen.

(b) Few correct answers were specific to hydrocarbons and referred to the strong C−H bonds and/or the non-polar nature of the molecules. Weaker responses did not refer specifically to hydrocarbon molecules.

(c) Correct identification of the process as 'cracking' was common.

(d) (i) The correct two isomers were shown in many responses. Common errors included the inclusion of a structure already drawn, although often with a different orientation on the page. Weaker responses showed structures that did not have the same molecular formula as hexane.

(ii) The best responses linked the extent of branching of **A**, **B** and hexane, to the amount of energy required to break intermolecular forces, to explain the difference in boiling points.
Many responses did not refer to energy involvement. It was common for explanations to be incorrectly given in terms of the inductive effect of alkyl groups or breaking covalent bonds during the process.

(e) (i) Candidates who had good knowledge of this reaction correctly identified both the reagent and a suitable catalyst. Weaker answers did not engage fully with the question and identified the catalyst used without identifying the reagent.

(ii) Application of Hess' Law in this context proved to be challenging. Good answers showed methodical and clear working. Many answers were given in terms of only two of the bond energy values provided.

(iii) The majority of equations used the correct formula for hexane and produced balanced equations. A common error showed the formula of hexane as C_6H_{12} and equations were not always balanced.

Question 4

(a) (i) Many answers were correct. Some answers described the name of the type of reaction rather than the mechanism.

(ii) The best answers showed a clear understanding of the propagation steps involved in a free radical substitution mechanism and applied this knowledge to the reaction. Common misconceptions included production of Cl_2 rather than HCl in step 1 and production of H• rather than Cl• in step 2. Equations to represent the termination step proved to be more straightforward. Weaker responses gave ionic reactants.

(iii) Homologous and homozygous were common incorrect answers.

(iv) Many responses assigned the correct term to denote a structure with three carbon atoms and no carbon-carbon double bonds. Common errors included incorrect numbering to represent the position of the chlorine atoms on the carbon chain or by omission of the prefix 'di'.

(v) Excellent understanding of the different types of isomerism was demonstrated by candidates that deduced the appropriate structural isomerism seen in molecules with the molecular formula $C_3H_6Cl_2$. Identification of the relevant type of stereoisomerism appeared to be more straightforward than the appropriate type of structural isomerism.

(b) Correct identification of sodium hydroxide as the reagent was seen frequently. Confusion over the relevant conditions required for this substitution reaction was common, with ethanol identified as the solvent instead of water.

(c) (i) Many answers described the correct colour change. Incorrect references of purple to colourless were seen in many responses.

(ii) The construction of the oxidation reaction using [O] to represent the oxidising agent proved challenging. Common errors included the formation of H_2 rather than H_2O or the production of an unbalanced equation with the correct reactants and products.

(d) (i) This question was answered well by most candidates. 'Hydrolysis' was a common incorrect answer.

(ii) The best answers engaged fully with the question and identified the relevant absorptions on Figure 4.2 and unambiguously identified the bonds responsible for these absorptions in the table. Many answers confirmed the presence of C=O and C-O bonds. It was less common for presence of C=C to be identified. The weakest answers did not include labels on Figure 4.2 to correspond to bonds identified in the table.

(iii) The best answers showed appropriate calculations to determine the number of carbon atoms in **S** from relative abundance of M^+ and $[M+1]^+$ peaks on the mass spectrum. The weakest answers used incorrect equations to calculate this value, for example 4.7/3.1 = 15 carbon atoms.

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Paper 9701/23
AS Level Structured Questions

Key messages

Candidates are advised to learn definitions precisely.

Candidates regularly missed out key words or key phrases when writing definitions in this paper.

General comments

Candidates struggled with the concept of intermolecular forces of attraction and their application to physical states and boiling/melting points. For example, **Question 1c(iv)**, statements describing why compounds exist in different physical states, at a specific temperature, often included the breaking of unspecified bonds.

The idea that 'forces of attraction exist between molecules' does require emphasising, for the different types of intermolecular attractions.

Enthalpy calculations requiring more than one step were poorly answered and only the stronger candidates performed well.

Stronger candidates performed well in **Question 4c** using a mass spectrum to identify an organic compound. More practice on the use of spectroscopy to identify compounds would be beneficial.

Comments on specific questions

Question 1

(a) (i) The number of protons, neutrons and electrons in an atom of the isotope chromium-52, was commonly correctly answered as 24, 28 and 24 respectively.

(ii) The difference between an atom of chromium-54 and chromium-52 was recognised as two neutrons by most candidates.

(iii) The information required, from a mass spectrum, to determine the relative atomic mass, A_r, of Cr, is the relative abundance of each isotope. There were many correct answers. Common errors included mention of unified atomic mass, moles or atomic mass.

(iv) Many candidates correctly stated that the fourth isotope of chromium had a relative isotopic mass of less than 52. Several candidates mentioned that the fourth isotope had the smallest % abundance but then did not refer to its relative isotopic mass.

(b) (i) The full electronic configuration of chromium was well known.

(ii) This question was well answered.

(c) (i) Candidates often identified Cr as the reduced species in the given half equation involving acidified $Cr_2O_7^{2-}$ and Cr^{3+}, but explanations using oxidation numbers were frequently incorrect with the numbers regularly reduced from 7 to 3 or 12 to 3.

Answers that avoided the use of oxidation numbers and stated that the Cr had gained electrons, were often correct. Other common errors stated that H^+ was reduced or that oxygen was lost.

(ii) This question was well answered.

(iii) Due to an issue with **Question 1(c)(iii)**, full marks have been awarded to all candidates for this question to ensure that no candidates were disadvantaged.

(iv) Methanal is a liquid at –30 °C because it has permanent dipole-permanent dipole forces of attraction between its molecules compared to the weaker instantaneous dipole-induced dipole intermolecular forces of attraction between gaseous CO_2 molecules.

This question proved difficult for many candidates as many stated that bonds are broken on melting. Several candidates compared the strength of bonds in methanal with those in CO_2. A common error was that hydrogen bonds were present in methanal.

(d) (i) The definition of 'dynamic equilibrium' was well answered.

(ii) The condition necessary to establish equilibrium is a 'closed system'. Many incorrect answers stated that a 'constant temperature or constant pressure was required'.

(iii) Many candidates recognised that the equilibrium, given in the question, between CrO_4^{2-}(aq) and $Cr_2O_7^{2-}$(aq), under acidic conditions, was an endothermic reaction. Candidates often gave a correct observation of the colour and position of the equilibrium mixture, when warmed.

When HC*l* (aq) was separately added to the equilibrium mixture, few candidates appreciated that the change, to an orange colour, was a result of the equilibrium shifting right to compensate for the added H^+(aq) ions.

(e) Many candidates correctly stated that the reaction between CrF_4 and water is a hydrolysis reaction. The equation for this reaction was less well known. Common errors included the introduction of $SiCl_4$ or SiF_4 into the equation.

Question 2

(a) (i) Many good answers were seen for the trend in atomic radii of the Period 3 elements.

(ii) Many answers gained partial credit for correctly stating that the large difference in ionic radii between A*l* and P is due, in part, to the A*l* losing its 3 valence electrons and P gaining 3 electrons, in its valence shell. Few candidates then qualified this with a creditworthy statement that the consequence is that Al then lost an outer shell whilst P retained its outer shell.

(b) (i) Most candidates were able to correctly complete the oxidation numbers of Period 3 elements, in their oxides. The pH of solutions of the Period 3 oxides was less well known with the most common' error being incorrect values for the pH of solutions of Na_2O and MgO.

(ii) Many candidates correctly stated that data for the pH of solutions of Al_2O_3 and SiO_2 was not given in the Table because these two oxides are insoluble. Frequent errors stated that these oxides were amphoteric or did not react with water.

(c) (i) The equation for the reaction between Na_2O and dilute hydrochloric acid was well answered.

(ii) Most candidates gave correct answers for the equation of the reaction between Al_2O_3 and a base to form $NaAlO_2$.

(d) (i) Candidates performed well in this question which required a statement on the trend in thermal stability of Group 2 nitrates down the group.

(ii) Apart from the metal oxide, the products from the thermal decomposition of Group 2 nitrates, are NO_2 and O_2.

A significant number of answers either omitted O_2 or gave N_2 and even CO_2 as incorrect answers.

Question 3

(a) The definition of 'empirical formula' was generally poorly answered. The main errors included the use of statements as:

- simplest molecular formula
- simplest ratio in a formula
- the simplest ratio atoms or simplest ratio of the elements (instead of simplest ratio of each atom of the elements in a compound).

(b) Many candidates correctly identified one of the two required cyclic structural isomers of cyclopentane, but the second isomer was often an incorrect rearrangement of the same isomer given in the question.

(c) (i) The type of bond fission of Cl_2, in the reaction using ultraviolet light, is homolytic fission. Common errors included the use of heterolytic and homologous fission.

(ii) The completion of the given partial equations for the two propagation steps between C_5H_{10} and Cl_2 was well answered. Common errors included the use of Cl_2 in propagation step 1 and a termination reaction in step 2.

(iii) Most candidates recognised that the equation, given in the question, representing the final step in the reaction, was a termination reaction.

(d) (i) The reagent for the formation of chlorocyclopentane from cyclopentene is gaseous hydrogen chloride. Many candidates incorrectly quoted hydrochloric acid.

(ii) Many candidates found this question challenging. The enthalpy change required in the question, ΔH_2, could be evaluated by first calculating the enthalpy change for reaction 1, and then using this value, together with ΔH_3, to complete the calculation.

Several candidates did not use all the data in Table 3.1, to calculate the enthalpy term for reaction 1, and candidates who did attempt to calculate an enthalpy term, often did not then use it correctly to evaluate ΔH_2.

(e) (i) Many correct answers were seen for the oxidative cleavage of cyclopentene to form pentanedioic acid. The most common errors were cyclic structures with no ring cleavage.

(ii) Most candidates gave correct answers showing clearly defined C=O and O−H bonds, for the absorptions, and correct labels on the infrared spectrum of the dicarboxylic acid (in **Question 3(e(i)**).

Question 4

(a) (i) The reduction of a carboxylic acid to a primary alcohol was recognised by many candidates as a reduction reaction. The most common errors described the reaction as an oxidation or dehydration reaction.

(ii) A suitable reagent for the conversion of an alcohol to a halogenoalkane can be $SOCl_2$, PCl_5, PCl_3, HCl(g) or the use of KCl and concentrated H_2SO_4 to generate HCl (g), in situ. Many candidates incorrectly quoted HCl as a suitable reagent without any qualifying state symbol.

(iii) Many candidates did not gain full credit because of incorrect equations or incorrect solvent and conditions. A common error in the equation was omitting either NaOH as a reactant or H_2O as a product. The condition of heat was often not included in answers and the ethanol solvent or the NaOH were sometimes stated as being in aqueous solution.

(iv) Many candidates correctly gave concentrated H_2SO_4 or Al_2O_3 and heat, as suitable reagents to convert an alcohol into an alkene. The most common errors were the omission of 'concentrated' for the acid and occasionally the inclusion of a mixture of the concentrated acid and Al_2O_3 and heat.

(b) (i) Addition is the only answer for describing the polymerisation of propene. This was correctly stated by many candidates.

(ii) The definition of stereoisomerism was often partially correct. Many candidates gained partial credit by stating that it was 'molecules with the same structural formula'. The inclusion of a statement explaining that the atoms or groups to have a different spatial arrangement was often not given. The most common errors were the omission of either a '3D arrangement' or no mention of 'atoms/groups'.

(iii) The drawings of a section of poly(propene), showing two repeat units was often the only creditworthy response for this question. After drawing a correct repeat unit, many candidates did not recognise the chiral C atoms, which would exhibit optical isomerism, and assumed that the type of stereoisomerism for this polymer was geometric/cis-trans or a form of structural isomerism.

(iv) The answers to the difficulties associated with the disposal of poly(propene) were varied. Many candidates gained some credit for stating that these polymers were not biodegradable. Stronger candidates often gave fully correct answers. The most common errors include the use of terms such as 'forms greenhouse gases', 'forms PAN', and did not consider the disposal of the polymers which was required in the question.

(c) (i) The name of the branched chain alkene was well answered. The most common incorrect answers were: 2,3-methylbut-1-ene or 2,3-dimethylbutene.

(ii) Few candidates correctly identified the correct alkene. Candidates did not identify that peaks at m/e = 41 and m/e = 43 were fragments from one of the alkenes, and that these fragments required a positive charge.

(iii) Many candidates used the formula: $\mathrm{n} = \frac{100 \times \text{abundance of } [\mathrm{M+1}]^+ \text{ ion}}{1.1 \times \text{abundance of } [\mathrm{M}]^+ \text{ ion}}$ to calculate the relative abundance of the $[M+1]^+$ peak.

Candidates who performed well understood that n was 6 here, as both alkenes given, had the same molecular formula of C_6H_{12}, and then continued to correctly calculate the relative abundance.

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Paper 9701/24
AS Level Structured Questions

Key messages

Candidates who gave the best answers were concise and precise. The accurate use of chemical terminology remains crucial in removing ambiguity from responses.

Candidates should be reminded to address 'explain' questions fully by stating facts or rules of thumb and then showing how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules, in particular for organic species, linking structural feature to mechanistic probabilities.

Candidates are advised to learn definitions precisely, which then affords them the opportunity to quiz themselves on whether their later responses adhere to that definition.

It is important that candidates show working in calculations to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later. The use of fractions in calculations should be avoided.

General comments

Some candidates were lacking in preparation, showing a lack of understanding of the chemistry involved for the question asked. An example of a lack of understanding of the question is giving the formula of a substance when asked for the name of a mechanism.

Candidates had sufficient time for all questions to be answered.

Very few candidates felt the need to write on extra pages. If extra pages are used, the question number must be clearly visible and obvious to which answer it relates.

Candidates are expected to balance all chemical equations.

Comments on specific questions

Question 1

(a) (i) The majority of candidates were given credit for stating that the Group VII elements gained electrons, rather than considering its role as an oxidising agent to remove electrons from another species. No credit was gained for the description of the trend in oxidising ability going down the group.

(ii) A well answered question with most candidates being able to write an equation for the reaction between aluminium and chlorine. Common errors were Al_2Cl_3 as a product of the reaction and Al_2O_3 as a reactant.

(iii) This question was found to be difficult. Many did not realise that iodine gas is purple or thought that hydrogen halides always appear as steamy or white fumes, whereas they only have this appearance in moist air, not in an enclosed container with no water present. The production of solid I_2 to give a black solid, on cooling, was also occasionally seen and gained credit.

(b) (i) Most candidates knew that the C*l*—C*l* bond is stronger, and many linked this to the shorter bond length. Some contradicted their reference to bond length by referring to relative sizes of ions rather than atoms. Very few referred to orbital overlap. There were some references to 'nuclear attraction' but there was either no reference to what that attraction of the nucleus was for, or specifying outer electrons instead of shared electrons. Some answers were entirely based on the relative strength of intermolecular forces rather than covalent bond strength leading to the incorrect conclusion that Br—Br had the stronger bond.

(ii) The majority knew that HC*l* is more stable, but the phrasing of some answers showed that many did not understand the question.

(iii) A complete definition was not well known. There were few completely correct definitions of enthalpy of formation. Candidates who did not gain full credit usually stated it was the 'energy needed' rather than the 'enthalpy change'.
Most candidates did not refer to the elements being in their standard states though they often referred to standard conditions, which is not the same.

(iv) There were many correct answers, though many did not account for the stoichiometric coefficients in the equation. Some produced the correct answer but then divided by three, giving the answer per mole of chlorine not per mole of reaction as specified in the equation.

(v) The shape was often correct, although many gave trigonal planar. The reason was often not phrased in terms of the numbers of bonding pairs and lone pairs of electrons and explanations were often lacking in detail. Some candidates stated that it is pyramidal because ammonia is.

(c) (i) The colours of the precipitates were well known. The reactions with concentrated sulfuric acid were less well known. Many stated that black or yellow solids would be produced with the bromide and sometimes with the chloride. Of those who did understand the chemistry, some did not appreciate that an acid-base reaction would occur with the chloride even though there would be no redox reaction, so incorrectly stated that there would be no reaction. Others described a green gas assuming that chlorine would be produced.

(ii) Many candidates identified the black solid as iodine, but the correct identification of sulfur and the gas was less common. Some gave the formula of sulfur as S_2. A significant number of candidates incorrectly stated that hydrogen is produced, or that $NaHSO_4$ is a gas. The identification of an unpleasant odour is not an observation for effervescence, here, a gas must be identified.

(d) (i) This question was challenging and only better performing candidates gained full credit. Many equated magnesium chloride with magnesium and stated that the bonding is metallic. Those who stated the bonding was ionic often stated that delocalised electrons, rather than mobile ions, were responsible for the conductivity. A significant number incorrectly stated that 'ions conducted electrons'. Some underdeveloped responses were see, where candidates only stated the type of bonding without referring to electrical conductivity. Confusion between a liquid and an aqueous solution was frequently seen.

(ii) There were many correct answers, although a significant number of candidates incorrectly stated that magnesium chloride is alkaline.

Question 2

(a) Many candidates found this question challenging. Many incorrectly identified the structure of aluminium oxide as giant covalent. Some candidates correctly identified both structures referred to molecules or intermolecular forces in both, contradicting the ionic bonding in Al_2O_3. There were also a significant number who incorrectly stated that covalent bonds are broken to melt P_4O_{10}.

(b) (i) There were many correct answers. mol^{-2} was a common incorrect answer. Other incorrect answers involved g, J and other assorted units.

(ii) Many responses did not account for volume to covert remaining moles at equilibrium into concentration. Some candidates incorrectly used the numbers of moles in the question, rather than calculating the moles of reactants remaining at equilibrium. Those who did often assumed an initial amount of CH_3OH of 0.4 mol rather than 0 mol, and the stoichiometry of $1CO:2H_2$ was often overlooked. Most gave answers to the required number of significant figures, but a few were unable

to gain full credit by giving 4 or more significant figures. Some candidates added all the moles together and gave mole fractions, confusing with K_p.

(iii) Many candidates did not appreciate that only temperature affects K_c, and stated that K_c increases because the equilibrium shifts to the right. Some candidates did not state what the effect on K_c.

(c) (i) Many good responses were seen, but some candidates gave a general answer in terms of increasing the proportion of effective collisions without stating how that was achieved. Some candidates did not mention that rate increases, and others only stated that rate increases without giving an explanation.

(ii) Many candidates attempted to give an equation incorporating P_4O_{10}. Some candidates did not interpret a dehydration reaction producing H_2O.

(iii) There were many correct answers, and most candidates could recall the reaction between P_4O_{10} and an excess of water. Equations where water was on both sides of the equation were not given credit.

Question 3

(a) (i) This question was answered well, with most candidates giving a correct skeletal structure of propanone. The most common incorrect answers were propan-2-ol or propanoic acid.

(ii) The yellow precipitate was well known. Some candidates incorrectly stated the observation as making the alkaline iodine solution or producing an orange precipitate, possibly due to confusion with 2,4-DNPH.

(iii) This question was answered well. Common incorrect responses were acid-base, condensation, addition and hydrolysis.

(iv) This was often well answered, however many candidates drew a second bond to make a double bond, and many candidates misunderstood the question, writing 'L' somewhere on the diagram. Some candidates who attempted to show how the π bond originated from p-orbitals were often inaccurate with their drawing, with the lobes crossing the σ-bond. Common incorrect responses showed a single line to represent a double bond, or p-orbitals not near C-atoms or overlapping.

(b) (i) Some correctly balanced equations for the reaction between propan-2-ol and sodium were seen. Common incorrect products were NaH, NaOH and H^+. Candidates who gave molecular formula did not gain credit.

(ii) Candidates who attempted an S_N1 mechanism often gained full credit. Many candidates unnecessarily redrew the nucleophile, which often resulted in responses showing the nucleophile attacking the 2-bromopropane and the intermediate which resulted in a confusion between S_N1 and S_N2 and so full credit could not be given.

(iii) Candidates who realised that the strength of the C—X bond was the critical factor usually deduced that the rate would decrease. Many candidates, however, gave the incorrect change because they concluded that bond polarity was the important factor. Some candidates misinterpreted the question and thought that 2-bromopropane was replacing 2-chloropropane. Some candidates referred to the incorrect bonds, usually H—X, and some referred to the bonds as if they were ionic. There was some confusion about these being reactions with the halogens, with references to chlorine being a stronger oxidising agent or chlorine being more reactive and thus the rate would increase.

(iv) While many correct answers were seen, a significant number did not state the correct products of combustion. Some responses did not take account of the oxygen atom already present in the molecule and thus 19/2 O_2 was a common incorrect answer. Some candidates gave 18(O) to represent $9O_2$ and did not gain credit.

Question 4

(a) (i) The definition of structural isomerism was well known, although some candidates had difficulty in expressing the idea of a molecular formula.

(ii) The structure of the isomer was well answered. Some candidates misunderstood the question and drew a structural isomer or a positional isomer of **P**. A few candidates redrew the cis isomer and this was commonly when candidates gave a displayed structure rather than a skeletal structure.

Weaker responses were seen for the explanation, with some candidates ambiguously referring to different groups on each side of the double bond, rather than on each carbon in the double bond or at each end of the double bond. Complete responses that referred to the lack of rotation about the double bond gained full credit.

(iii) Most candidates recognised this as an addition, but some did not specify the type or stated that it was nucleophilic.

(iv) Many candidates recognised propanone as one product, but fewer gave ethanoic acid as the other. Ethanal and CO_2 were seen commonly. Most responses giving the correct products were correctly balanced. Some candidates did not recognise that the molecule would react in a way that produced two fragments.

(v) Few responses gained full credit. Many realised that alkyl groups, the inductive effect and tertiary/secondary structures were involved but were unable to articulate their thoughts into a correct answer. A common error was to state that the products themselves had different stabilities, rather than the carbocation intermediates from which they were produced. Some candidates incorrectly stated that the products themselves were carbocations.

(vi) Only the better performing candidates were able to gain full credit on this question. Most candidates did not draw the correct structure of the positive ion responsible for each peak; different numbers of H atoms and different charges (including negative) were common. Even responses that recognised that the difference was due to the isomers of bromine sometimes gave the incorrect mass number, with 35 and 37 being common. 80 and 82 were other common incorrect responses, usually accompanied by the absence of a H atom. Responses that gave two correct structures with the correct isotopes did not state that the structures were positive ions – although partial credit was given for two fully correct structures with missing positive charges on each. Many candidates did not attempt an answer.

(b) (i) Many responses gave KCN as the reagent, and most stated that KCN must be dissolved in ethanol (though some wrote ethanal or ethanoic acid). Common incorrect responses gave HCN as the reagent.

(ii) Many candidates correctly gave the product as an acid, and many correct equations were seen. A common error in the product was giving $(CH_3)_2COOH$ rather than $(CH_3)_2CHCOOH$. Other common errors were to omit the HCl from the equation, give NH_3 as a product and give HCN as a product.

(iii) Most candidates correctly recognised the type of reaction as esterification/condensation. candidates who chose to draw the ester group rather than name it were often unsuccessful due to the omission of linking bonds. There were the fewest correct responses for the molecular formula, with many candidates giving semi-structural formulas instead.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- clearly cross out and replace any work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were usually provided by centres. These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out the experiments using the same solutions, solid samples and equipment as the candidates so that supervisor / candidate results and observations can be compared and the quality of candidates' practical work be assessed fairly. Supervisors should ensure that more than one titration is carried out and that their results are concordant. It is advisable that the best practical chemist in the centre carries out the experiments. Centres should provide results for each laboratory and practical session.

Issues with supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issues have already been communicated to Cambridge I prior to the examination period.

Many candidates found the questions challenging. The recording and presentation of results varied significantly. **Question 3(a)(i)** required candidates to devise their own tests. Candidates should make use of the qualitative analysis notes provided when selecting and describing chemical tests. In **Question 3(a)(i)** and **3(c)**, use of the term 'precipitate' was often incorrect as it was used to describe an insoluble solid added to a solution. A precipitate may be formed only when two solutions are mixed.

Comments on specific questions

Question 1

(a) Candidates were prepared well for this titration experiment. Candidates should record their burette readings for their rough titration and then carry out at least two accurate titrations.

Candidates are encouraged to present their table of results as 'FIT' – Final reading / volume, Initial reading / volume, Titre. Each heading should have correctly displayed units / cm^3, in cm^3 or (cm^3), not ml.

As a burette is accurate to 0.05 cm^3, results should be recorded to either #.#5 or #.#0 cm^3. This does not apply to the titre.

The titration should be repeated until a result is obtained that is within 0.10 cm^3 of another result.

Most reported titrations were accurate when compared to those of the supervisor.

(b) The values selected to calculate a mean titre should be within 0.20 cm^3. Some candidates selected results outside this range and occasionally included the rough titre, which should not be used.

(c) (i) Many candidates were awarded this significant figure mark which required the answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to be given to 3–4 significant figures. Common errors included incorrectly calculating an answer of 90 for **(c)(iv)**. Presentation of results in standard form should be encouraged. It was clear that candidates giving an example answer of 5.00×10^{-2} were much more likely to give an answer to the required number of significant figures rather than presented as 0.0500 where rounding to 0.05 and hence only one significant figure was seen.

(ii) This was answered well. Some candidates did not covert the titre to dm^3.

(iii) The majority of candidates were able to apply the correct mole ratio of 2.5 although a small number of candidates multiplied by 5, or by 2/5.

(iv) This question asked for the calculation of the relative molecular mass, M_r, of the ethanedioic acid in **FA 1**. On page 2 of the question paper, the identity of **FA 1** is given as aqueous ethanedioic acid, $(COOH)_2 \bullet \mathbf{x}H_2O$. A_r values cannot be used to calculate the M_r, as the value of **x** is not known at this stage. Despite this, 90.(0) was often seen as a final answer. The M_r should be calculated by using the mass of **FA 1** in 1 dm^3 (6.20 g) and dividing this by the concentration of **FA 1** calculated in **(c)(iii)**.

(v) Calculation of the M_r of anhydrous ethanedioic acid $(COOH)_2$ (90) *was* required. This value should be subtracted from **(c)(iv)**, divided by 18 and the answer given as an integer. Some candidates did the calculation correctly but did not round correctly or did not give the answer as an integer. It was possible to re-start this calculation using data from **(c)(iii)** rather than **(c)(iv)** and some candidates provided detailed correct working to show how their answer had been obtained, albeit by a more challenging route.

(d) Ethanedioic acid is a reactant, therefore suggesting that the **FA 3** (sulfuric acid) is added to acidify the reaction / solution is not precise enough. **FA 3** is acting as the source of the H^+ ions in the reaction equation. Incorrect answers included the **FA 3** acting as a catalyst or as a buffer.

Question 2

(a) Many candidates gave accurate headings in their table. Candidates should refer directly to the method and the measurements they were asked to take when writing their headings. Common errors included reference to the solid after heating as '**FA 4**' (at this point it had undergone decomposition and was no longer **FA 4**) or headings that did not allow the two masses after heating to be clearly distinguished. Some candidates did not follow the instructions and only heated the crucible and contents once.

Marks **I** and **II** were unavailable to candidates that only heated the solid once. Many candidates were not awarded mark **II** due to the difference in masses between 1st and 2nd heating being too great.

Most candidates used a mass of **FA 4** within an acceptable range. Many candidates confused 'mass of **FA 4** used' with the change in mass of the solid on heating, i.e. the mass of water lost. The mass of **FA 4** used is the mass of **FA 4** added to the crucible initially.

Most candidates were awarded both quality marks for this question.

(b) (i) Many candidates were able to use the Periodic Table to calculate the M_r of $ZnSO_4$ and hence to calculate moles of residue. In both parts of the question, candidates could gain credit by using incorrectly calculated masses in the table in **(a)**.

(ii) Candidates were required to show their working; to produce an expression and evaluate it as an integer. Some candidates were able to recognise that **y** should be calculated from the ratio of the moles of water : moles of residue from **(b)(i)**. Other (more complex) expressions using a similar calculation to that performed in **Question 1** were equally valid. A small number of candidates gave an incorrect expression but were able to obtain partial credit for correctly evaluating it. Some candidates found this question challenging. Centres are encouraged to practise this experiment and the associated calculations.

(c) The most common correct answers involved the decomposition of ethanedioic acid or evaporation. Some candidates noted that the decomposition of ethanedioic acid would also produce carbon dioxide and therefore thermal decomposition is not a valid technique. Incorrect answers often referred to percentage error issues or did not understand the implications of ethanedioic acid being a hydrated organic compound rather than the hydrated inorganic salt in **Question 2**.

Question 3

(a) (i) This question proved very challenging with few candidates obtaining full credit. The question required candidates to devise a series of tests to indicate whether the following three were present in **FA 5:** zinc ions, sulfate ions and water of crystallisation.

Some candidates were able to show that water of crystallisation was present by gently heating the solid in a hard-glass test-tube and observing water vapour, steam or condensation. Some candidates attempted to prove that water of crystallisation was present by heating the sample and demonstrating mass loss. This is not a qualitative test to show that water of crystallisation is present as the mass loss could be caused by a different decomposition product.

Tests for zinc ions and sulfate ions, as given in the qualitative analysis notes, rely on the formation and solubility of white precipitates. **FA 5** was supplied as a white solid. The formation of a white precipitate cannot be judged by adding a white solid to a reagent. The required tests should have been carried out by initially forming an aqueous solution of **FA 5** by dissolving the solid in water. It was common to see this stage omitted. The results of tests with solid **FA 5** added to NaOH(aq), NH_3(aq) or aqueous barium nitrate / chloride were not valid. Candidates reporting a white precipitate, soluble in excess alkali incorrectly concluded that zinc ions were present. Their observation was an excess of solid **FA 5** dissolving in the alkali. Candidates who made a solution of **FA 5** were able to observe a white precipitate with NH_3(aq) (or NaOH(aq)) that was insoluble in excess alkali and correctly conclude that **FA 5** did not contain zinc ions.

Similarly, a solution of **FA 5** should have been used when testing for sulfate ions. Most candidates were able to identify a white precipitate with aqueous barium nitrate or barium chloride. The guidance on page 7 of the question paper states that 'where reagents are selected for use in a test, the name or correct formula of the element or compound should be given'. Despite this many errors were observed including writing the barium reagent as Ba^{2+} and giving the formula of barium nitrate as $BaNO_3$ or barium chloride as $BaCl$. When adding a dilute strong acid, some candidates were able to use dilute hydrochloric or nitric acid and show that the white precipitate did not dissolve, identifying the ion as sulfate rather than sulfite. Common errors included missing out this test, not specifying which dilute strong acid was used or using sulfuric acid which invalidates the test by adding sulfate ions. Some candidates used acidified $KMnO_4$(aq) as an alternative reagent which was acceptable provided a precise description of the test was given - the $KMnO_4$(aq) should remain purple or not be decolourised rather than ‘no change’.

(ii) This question was dependent on the tests in **(a)(i)**. The question indicated that candidates should complete the table using ticks and crosses. Some candidates only used ticks and left one or more boxes blank.

(b) (i) Observations on heating **FA 6** were often not recorded well. When carrying out an unfamiliar test, candidates should observe the initial and final appearance. Oxygen was produced when heating the solid. Many candidates were able to observe the gas relighting a glowing splint. Some candidates incorrectly identified ammonia or did not test the gas.

(ii) Most candidates recorded shades of purple or blue-black here suggesting that **FA 6** had not been heated enough in **(b)(i)**. Some candidates were able to observe the dark green solution produced.

(c) (i) This question required candidates to carry out seven tests to identify the common metal present in **FA 7**, **FA 8** and **FA 9**. This was done well. Where gas tests were carried out, oxygen was usually positively identified (although some candidates didn't record any gas tests at all). The colour changes for **FA 7** were often clearly identified.

Many candidates correctly identified 'no change' for **FA 8, Test 1 and 3**. The 'no change' for **FA 9 Test 2** was less frequently seen, with many candidates recording a black solution or precipitate here.

(ii) An off-white precipitate rapidly turning brown on standing (**FA 8 Test 2**) is listed in the qualitative analysis notes as Mn^{2+}. This showed that the common metal was Mn.

Many candidates correctly identified manganese or Mn. Some candidates gave their answer as Mn^{2+} which was correct for **FA 8**, but not **FA 6/7** or **FA 9**. The most common incorrect answer was Iron.

(iii) Fewer candidates could give the correct oxidation states after stating that the metal was Mn. The dark purple colouration of **FA 7** suggested potassium manganate(VII) and this solution was clearly an oxidising agent in **Test 3**. Candidates had previously used the same solution, labelled as **FA 2**, in the titration in **Question 1**.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully,
- follow the instructions in the method,
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data,
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance,
- use blue or black pen to complete the paper as instructed on the front cover; the use of pencil is only appropriate for graphical work,
- cross out and replace work that is to be changed; examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks must be given.

These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the unknowns and reagents in **Question 3**. Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that Supervisor/candidate results and observations can be compared and the quality of candidates' practical work assessed fairly. It is advisable that the best practical chemist in the centre carries out the experiments.

Issues with supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issue has already been communicated to Cambridge International prior to the examination.

Almost all candidates were able to complete the paper within the time allowed.

It is important that candidates read the initial information given in advance of **Question 1** and **Question 3**. These sections are designed to aid the candidates in their work as are the Qualitative analysis notes given at the end of the paper.

Comments on specific questions

Question 1

Candidates presented their data as expected. Full credit was awarded to most candidates for completing the experiment accurately. Most candidates were well-prepared in terms of the translation of their data into a graph.

(a) Most candidates presented their data in a clear, logical fashion. Data was complete in terms of both the detail required and the number of experiments. Common errors included not recording the number of seconds to a whole number and missing or incorrect units for the rate of reaction column. Candidates are reminded to take care when rounding calculated values – the rates of

reaction in this case. Most candidates made sensible decisions in terms of selecting volumes for their additional experiments.

(b) (i) Candidates scored well for their attempts at the graph. Some candidates overlooked the instruction to include the origin when planning their scales. Although the plotting of points was done well, candidates are reminded that if a value does not fall exactly on a particular grid line, then it should not be plotted on that line.

(ii) The question instructed candidates to 'Show clearly on the graph how you worked out your answer'. Some candidates ignored this instruction and could not receive full credit. Candidates were expected to show that they had identified the position of 7.5 on the *x*-axis and had correctly read the corresponding *y*-axis value.

(c) The difference between proportional and directly proportional was not well understood by most candidates. In most cases an attempt at a line of best fit on the diagram provided would have been useful in supporting the response.

Question 2

Candidates were well-prepared for **parts (a)** and **(b)** but many struggled with **part (c)**.

(a) Candidates are reminded to take care when recording their data to ensure that the correct precision is used. Thermometer readings should be recorded to one decimal place ending in either zero or five, and balance readings should be given to either two or three decimal places depending on the equipment available. Most candidates carried out the experiment accurately and recorded the temperature drop expected.

(b) (i) This calculation was completed well by many candidates. The mark was sometimes lost for not using 32.1 as the relative atomic mass of sulfur. Candidates should always check which value to use by referring to the data in the Periodic Table provided.

(ii) Compared with previous years, few candidates incorrectly used 4.2 instead of 4.18 for the specific heat capacity of water. A common error was to use the mass of solid in place of the mass of the water.

(iii) Stronger candidates appreciated the need to divide the energy change by the number of moles to answer this question. . Errors included an incorrect sign or not dividing the energy change by 1000 to convert J to kJ.

(c) This question discriminated well. Many candidates gained partial credit by recognising that a Hess's cycle is required. Many candidates selected an inappropriate additional experiment such as dehydration of the hydrated salt or attempting to calculate an enthalpy change of formation.

Question 3

The introductory information at the beginning of the question combined with the information in the Qualitative analysis notes provides many useful pointers on how candidates should answer this type of question. Candidates are reminded that when observing colours, they are expected to state what the colour refers to e.g. a solution. Candidates should not do additional tests. No credit will be given for these additional tests.

(a) (i) Most candidateswere awarded partial credit.. Common errors included recording 'turns milky' rather than 'white ppt.' when testing for carbon dioxide in Test 3, missing the fizzing between **FA 5** and sodium carbonate, also in Test 3, and by recording 'turns purple' rather than 'no change' in Test 5. Some candidates also added an additional step to Test 4 – adding a dilute acid. Candidates are reminded that the cation tests with aqueous sodium hydroxide and aqueous ammonia require the effect of an excess of the reagent to be described.

(ii) Many candidates identified three or four of the ions present but H^+ as one of the cations was rarely seen as an answer.

(b) (i) Candidates were less familiar with the tests for organic compounds compared with the tests in the previous question part. The triiodomethane (iodoform) test was not well done.

(ii) Candidates were given credit for identifying both **FA 6** and **FA 7** without a full set of supporting evidence from their observations. Few candidates were awarded full credit. One common error was that methanoic acid gives a positive iodoform test.

(c) This question discriminated well. The omission of water as a secondary product was a common error. Candidates were unfamiliar with the formulae of the compounds named.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully, as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- cross out and replace work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were given by many centres. These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that Supervisor/candidate results and observations can be compared and the quality of candidates' practical work assessed fairly.

Any issues with the supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issue has already been communicated to Cambridge prior to the examination.

Many candidates found the qualitative analysis question more demanding. Almost all the candidates were able to complete the paper within the time allowed.

Comments on specific questions

Question 1

The quality of practical work for this question was good. Initial aspects of the calculations were performed well by many candidates, but most found the latter parts of the question demanding.

Candidates should read the rubric carefully. Questions are worded to help candidates select appropriate data for their calculations.

(a) Candidates are encouraged to draw a table for their results before carrying out the method. This would avoid omitting balance readings or calculated values.

Many candidates were able to write clear headings with correct units and record readings for temperature and mass to the correct degree of precision. Errors in headings and units included 'initial/final mass,' use of 'weight' instead of mass, and 'C°'.

Whilst the majority of candidates gave their balance readings either to 2 decimal places (dp) or to 3 dp, a sizable minority gave their thermometer readings to integer values instead of the nearest .0 or .5.

(b) (i) Many candidates gained both marks for this part of the question. Loss of a mark was usually due to carrying out the calculation based on the number of moles of acid added, despite having been told that the acid used was in excess.

Some candidates rounded to 1 significant figure. Candidates are reminded that their calculated values should reflect the precision of their measuring apparatus.

(ii) Many candidates correctly calculated the energy changes. A common error was to use the mass of **FB 2** or **FB 3** as well as or instead of the 20 cm^3 (20 g) of distilled water. The value given for c (= 4.18 kJ kg^{-1} K^{-1}) is for water and not for the solution.

Some candidates incorrectly used c = 4.2 kJ kg^{-1} K^{-1}; candidates are expected to use the data supplied in the paper. Another error was to write down all the numbers on the calculator rather than considering how many significant figures were appropriate in this question.

(iii) Most candidates gained partial credit for this question, realising the need to divide the energy change by the amount of carbonate used. Some candidates omitted the division by 1000, or assigned signs to the enthalpy changes the wrong way around.

(iv) Strong candidates gained both full credit for this question. Candidates seem to have limited experience of constructing Hess Cycles. Even in answers where candidates had the arrows pointing in the correct direction, an incorrect set of substances was frequently seen at the base of the cycle, with many candidates appearing to be attempting to use enthalpies of formation. Arrows were only labelled correctly by a small number of candidates.

There were few correct answers for the ΔH calculation. Whilst several candidates understood the need to reverse the sign of ΔH_2, very few also identified the factor of 2 required due to the number of moles of $NaHCO_3$ shown in the reaction equation.

Question 2

Most candidates appeared to be well practised in titration exercises as they displayed their results correctly and achieved one or more accuracy marks. Candidates were less successful at processing their results.

(a) Many candidates scored highly for the presentation of their titration results. Candidates should be reminded that the burette readings for the rough titration must be recorded either in the space provided or clearly labelled in the main titration table.

Column headings were good; some candidates used 'initial' rather than initial volume. 'Amount' instead of 'volume' was also seen – candidates should be aware that 'amount' refers to moles. The best heading for the volume added is 'titre'.

Most candidates recognised that the final titre needs to be concordant (within 0.10 cm^3 of another) and most gained at least partial credit for accuracy.

(b) Most candidates calculated their mean value correctly, clearly showing their working. Only titres within 0.20 cm^3 should be used to calculate the mean and it should be correctly rounded to 2 dp.

(c) (i) Due to the concentrations of reactants shown in **(a)** and the precision of the apparatus used, answers in **(c)(ii)** and **(c)(iii)** should be given to 3 or 4 significant figures (sf). Many candidates gave at least one answer to 2 sf and so did not achieve the mark. It is worth noting that it is sometimes necessary to add trailing zeroes to provide the correct precision.

(ii) Both answers to this part of the question were usually correct.

(iii) Both parts of this question proved challenging to many candidates. In the first part of the question, most candidates did not scale up by a factor of 40, thus calculating the mass present in their 25 cm^3 sample, rather than the 1 dm^3 required by the question.

Many candidates failed to realise the need to carry out a subtraction from 17.20 in the second part. Some candidates with relatively high titres obtained an answer greater than 17.20 in the first part of **(c)(iii)**. These candidates tended to invert the calculation, thus obtaining an incorrect percentage purity. For such candidates, a negative percentage purity, or a comment on the impossibility of their data, was required.

(d) Few candidates scored both marks for this question. Many candidates correctly stated that the ΔH_1 value would become smaller; few candidates appreciated the requirement to assume that the impurity does not react with hydrochloric acid.

Question 3

Many candidates would have benefited from reading the introductory information given in the question thoroughly. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, adding a solid to a solution and calling it a precipitate is incorrect. 'Gas released' is not an observation and is not credited in place of 'effervescence'.

(a) (i) Many candidates attempted to carry out a test with silver nitrate to identify the halide ion but gained only partial credit. Some candidates omitted to identify the silver compound used; some did not use ammonia to test the solubility of the precipitate obtained.

Candidates should read the question carefully; this question required the formula of the sodium halide impurity, therefore NaCl is the only acceptable answer, and Cl^- is not sufficient.

(ii) Most candidates appeared not to be aware of the need to remove carbonate ions before carrying out a test with silver nitrate.

(b) (i) Candidates are encouraged to record both the colour and the state when describing observations. The correct final observation required the presence of a black *solid*. Despite the instructions in the question, some candidates did not heat sufficiently gently at first and therefore missed 'condensation' as an observation. The fact that the solid moves around whilst being heated was noted by only a small number of candidates.

(ii) Many candidates gave the correct final colour for the solution, although many incorrectly commented on the presence of a precipitate. Most candidates reported fizzing but far fewer went on to test the gas produced. Amongst those who did test for carbon dioxide, many candidates reported the limewater going 'cloudy' or 'milky' rather than producing a white precipitate. The correct test for carbon dioxide is clearly stated in the Qualitative analysis notes.

(iii) The observations in Tests 1 and 2 were made more challenging for candidates due to variable quantities of HCl left in the solution after **b(ii)**. Candidates had to ensure that they continued adding alkali until it was in excess.

Use of the Qualitative analysis notes for Tests 1 and 2 enabled candidates to select colour observations and descriptions of gas tests more likely to gain them marks. Candidates must consider what familiar reagents are testing for and the probable observations.

Test 3 had several possible observations. Candidates should describe all the changes that they notice. Few candidates noted the colour of the solution becoming paler in Test 3, and only few successfully tested for hydrogen gas.

(c) (i) Many candidates gave good answers to this question. A few candidates incorrectly identified the colour of the initial precipitate as being evidence for Cr^{3+} and subsequently gave an incorrect description of its solubility.

In the second part of the test, a common incorrect answer involved the solution 'remaining colourless'. Candidates should have recognised that when a purple solution was added to a colourless solution, a colour change from purple to colourless occurred.

(ii) This demanding question was rarely answered in full. Many candidates gave partially correct answers. To gain credit, the answer had to relate the colour change seen in the previous test to the type of reaction taking place.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- clearly cross out and replace any work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were usually provided by centres. These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out the experiments using the same solutions, solid samples and equipment as the candidates so that supervisor / candidate results and observations can be compared and the quality of candidates' practical work be assessed fairly. Supervisors should ensure that more than one titration is carried out and that their results are concordant. It is advisable that the best practical chemist in the centre carries out the experiments. Centres should provide results for each laboratory and practical session.

Issues with supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issues have already been communicated to Cambridge I prior to the examination period.

Many candidates found the questions challenging. The recording and presentation of results varied significantly. **Question 3(a)(i)** required candidates to devise their own tests. Candidates should make use of the qualitative analysis notes provided when selecting and describing chemical tests. In **Question 3(a)(i)** and **3(c)**, use of the term 'precipitate' was often incorrect as it was used to describe an insoluble solid added to a solution. A precipitate may be formed only when two solutions are mixed.

Comments on specific questions

Question 1

(a) Candidates were prepared well for this titration experiment. Candidates should record their burette readings for their rough titration and then carry out at least two accurate titrations.

Candidates are encouraged to present their table of results as 'FIT' – Final reading / volume, Initial reading / volume, Titre. Each heading should have correctly displayed units / cm^3, in cm^3 or (cm^3), not ml.

As a burette is accurate to 0.05 cm^3, results should be recorded to either #.#5 or #.#0 cm^3. This does not apply to the titre.

The titration should be repeated until a result is obtained that is within 0.10 cm^3 of another result.

Most reported titrations were accurate when compared to those of the supervisor.

(b) The values selected to calculate a mean titre should be within 0.20 cm^3. Some candidates selected results outside this range and occasionally included the rough titre, which should not be used.

(c) (i) Many candidates were awarded this significant figure mark which required the answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to be given to 3–4 significant figures. Common errors included incorrectly calculating an answer of 90 for **(c)(iv)**. Presentation of results in standard form should be encouraged. It was clear that candidates giving an example answer of 5.00×10^{-2} were much more likely to give an answer to the required number of significant figures rather than presented as 0.0500 where rounding to 0.05 and hence only one significant figure was seen.

(ii) This was answered well. Some candidates did not covert the titre to dm^3.

(iii) The majority of candidates were able to apply the correct mole ratio of 2.5 although a small number of candidates multiplied by 5, or by 2/5.

(iv) This question asked for the calculation of the relative molecular mass, M_r, of the ethanedioic acid in **FA 1**. On page 2 of the question paper, the identity of **FA 1** is given as aqueous ethanedioic acid, $(COOH)_2 \bullet \mathbf{x}H_2O$. A_r values cannot be used to calculate the M_r, as the value of **x** is not known at this stage. Despite this, 90.(0) was often seen as a final answer. The M_r should be calculated by using the mass of **FA 1** in 1 dm^3 (6.20 g) and dividing this by the concentration of **FA 1** calculated in **(c)(iii)**.

(v) Calculation of the M_r of anhydrous ethanedioic acid $(COOH)_2$ (90) *was* required. This value should be subtracted from **(c)(iv)**, divided by 18 and the answer given as an integer. Some candidates did the calculation correctly but did not round correctly or did not give the answer as an integer. It was possible to re-start this calculation using data from **(c)(iii)** rather than **(c)(iv)** and some candidates provided detailed correct working to show how their answer had been obtained, albeit by a more challenging route.

(d) Ethanedioic acid is a reactant, therefore suggesting that the **FA 3** (sulfuric acid) is added to acidify the reaction / solution is not precise enough. **FA 3** is acting as the source of the H^+ ions in the reaction equation. Incorrect answers included the **FA 3** acting as a catalyst or as a buffer.

Question 2

(a) Many candidates gave accurate headings in their table. Candidates should refer directly to the method and the measurements they were asked to take when writing their headings. Common errors included reference to the solid after heating as '**FA 4**' (at this point it had undergone decomposition and was no longer **FA 4**) or headings that did not allow the two masses after heating to be clearly distinguished. Some candidates did not follow the instructions and only heated the crucible and contents once.

Marks **I** and **II** were unavailable to candidates that only heated the solid once. Many candidates were not awarded mark **II** due to the difference in masses between 1st and 2nd heating being too great.

Most candidates used a mass of **FA 4** within an acceptable range. Many candidates confused 'mass of **FA 4** used' with the change in mass of the solid on heating, i.e. the mass of water lost. The mass of **FA 4** used is the mass of **FA 4** added to the crucible initially.

Most candidates were awarded both quality marks for this question.

(b) (i) Many candidates were able to use the Periodic Table to calculate the M_r of $ZnSO_4$ and hence to calculate moles of residue. In both parts of the question, candidates could gain credit by using incorrectly calculated masses in the table in **(a)**.

(ii) Candidates were required to show their working; to produce an expression and evaluate it as an integer. Some candidates were able to recognise that **y** should be calculated from the ratio of the moles of water : moles of residue from **(b)(i)**. Other (more complex) expressions using a similar calculation to that performed in **Question 1** were equally valid. A small number of candidates gave an incorrect expression but were able to obtain partial credit for correctly evaluating it. Some candidates found this question challenging. Centres are encouraged to practise this experiment and the associated calculations.

(c) The most common correct answers involved the decomposition of ethanedioic acid or evaporation. Some candidates noted that the decomposition of ethanedioic acid would also produce carbon dioxide and therefore thermal decomposition is not a valid technique. Incorrect answers often referred to percentage error issues or did not understand the implications of ethanedioic acid being a hydrated organic compound rather than the hydrated inorganic salt in **Question 2**.

Question 3

(a) (i) This question proved very challenging with few candidates obtaining full credit. The question required candidates to devise a series of tests to indicate whether the following three were present in **FA 5:** zinc ions, sulfate ions and water of crystallisation.

Some candidates were able to show that water of crystallisation was present by gently heating the solid in a hard-glass test-tube and observing water vapour, steam or condensation. Some candidates attempted to prove that water of crystallisation was present by heating the sample and demonstrating mass loss. This is not a qualitative test to show that water of crystallisation is present as the mass loss could be caused by a different decomposition product.

Tests for zinc ions and sulfate ions, as given in the qualitative analysis notes, rely on the formation and solubility of white precipitates. **FA 5** was supplied as a white solid. The formation of a white precipitate cannot be judged by adding a white solid to a reagent. The required tests should have been carried out by initially forming an aqueous solution of **FA 5** by dissolving the solid in water. It was common to see this stage omitted. The results of tests with solid **FA 5** added to NaOH(aq), NH_3(aq) or aqueous barium nitrate / chloride were not valid. Candidates reporting a white precipitate, soluble in excess alkali incorrectly concluded that zinc ions were present. Their observation was an excess of solid **FA 5** dissolving in the alkali. Candidates who made a solution of **FA 5** were able to observe a white precipitate with NH_3(aq) (or NaOH(aq)) that was insoluble in excess alkali and correctly conclude that **FA 5** did not contain zinc ions.

Similarly, a solution of **FA 5** should have been used when testing for sulfate ions. Most candidates were able to identify a white precipitate with aqueous barium nitrate or barium chloride. The guidance on page 7 of the question paper states that 'where reagents are selected for use in a test, the name or correct formula of the element or compound should be given'. Despite this many errors were observed including writing the barium reagent as Ba^{2+} and giving the formula of barium nitrate as $BaNO_3$ or barium chloride as $BaCl$. When adding a dilute strong acid, some candidates were able to use dilute hydrochloric or nitric acid and show that the white precipitate did not dissolve, identifying the ion as sulfate rather than sulfite. Common errors included missing out this test, not specifying which dilute strong acid was used or using sulfuric acid which invalidates the test by adding sulfate ions. Some candidates used acidified $KMnO_4$(aq) as an alternative reagent which was acceptable provided a precise description of the test was given - the $KMnO_4$(aq) should remain purple or not be decolourised rather than ‘no change’.

(ii) This question was dependent on the tests in **(a)(i)**. The question indicated that candidates should complete the table using ticks and crosses. Some candidates only used ticks and left one or more boxes blank.

(b) (i) Observations on heating **FA 6** were often not recorded well. When carrying out an unfamiliar test, candidates should observe the initial and final appearance. Oxygen was produced when heating the solid. Many candidates were able to observe the gas relighting a glowing splint. Some candidates incorrectly identified ammonia or did not test the gas.

(ii) Most candidates recorded shades of purple or blue-black here suggesting that **FA 6** had not been heated enough in **(b)(i)**. Some candidates were able to observe the dark green solution produced.

(c) (i) This question required candidates to carry out seven tests to identify the common metal present in **FA 7**, **FA 8** and **FA 9**. This was done well. Where gas tests were carried out, oxygen was usually positively identified (although some candidates didn't record any gas tests at all). The colour changes for **FA 7** were often clearly identified.

Many candidates correctly identified 'no change' for **FA 8, Test 1 and 3**. The 'no change' for **FA 9 Test 2** was less frequently seen, with many candidates recording a black solution or precipitate here.

(ii) An off-white precipitate rapidly turning brown on standing (**FA 8 Test 2**) is listed in the qualitative analysis notes as Mn^{2+}. This showed that the common metal was Mn.

Many candidates correctly identified manganese or Mn. Some candidates gave their answer as Mn^{2+} which was correct for **FA 8**, but not **FA 6/7** or **FA 9**. The most common incorrect answer was Iron.

(iii) Fewer candidates could give the correct oxidation states after stating that the metal was Mn. The dark purple colouration of **FA 7** suggested potassium manganate(VII) and this solution was clearly an oxidising agent in **Test 3**. Candidates had previously used the same solution, labelled as **FA 2**, in the titration in **Question 1**.

CHEMISTRY

Paper 9701/36
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- cross out and replace work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were provided by many centres. These results are used when awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that Supervisor/candidate results and observations can be compared and the quality of candidates' practical work assessed fairly. It is advisable that the best practical chemist in the centre carries out the experiments.

Issues with the supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issue has already been communicated to Cambridge prior to the examination.

Many candidates found the qualitative analysis question more demanding. Almost all the candidates were able to complete the paper within the time allowed.

Comments on specific questions

Question 1

For almost all centres, this proved a reliable experiment with most Supervisors and candidates producing a mass ratio within the expected range. In cases where the Supervisor's value was outside the range, the candidates were usually within the range of the theoretical value.

(a) Many candidates found this question challenging and missed out on full marks. To improve future performance, please keep the following common pitfall in mind:

- ensure you distinguish between the starting material (**FB 1**) and the residue remaining in the crucible after heating,
- remember to record all required measurements, including the final 4th balance reading,

- it is important to list all calculated values; many candidates omitted the "mass lost",
- take care to correctly identify results, as some candidates confused the "mass lost" with the "residue" remaining in the crucible.

Other than the candidates who recorded just one mass of crucible and residue after heating, most candidates recorded two masses within the tolerance of +0.02 g and –0.05 g between the 1st and 2nd weighings after heating and reheating.

Candidates occasionally lost one mark due to calculation errors in subtractions. However, the most frequent issue preventing candidates from earning this mark was incomplete recording of all three required mass calculations. A few candidates had the value for **FB 1** outside range specified.

Many candidates gained full credit for accuracy in this question; only a few produced results that were outside the accepted range for the mass ratio.

Centres should be encouraged to have enough 2 decimal place (dp) balances for their candidates; 3 dp balances appeared to cause more errors and using them is more time consuming.

(b) (i) Most candidates successfully calculated the amount of water lost using their value for mass lost. Some candidates rounded their answer to one significant figure (sf), usually when their calculated value was 0.05(00).

(ii) Many candidates correctly calculated the amount of **FB 1**, but some used 32 instead of 32.1 for the A_r of sulfur.

(iii) The most common errors were not giving the final answer as an integer and incorrect rounding.

(c) (i) The question asked for the difference in appearance of **FB 1** and the residue; only a few candidates described the appearance of the solid before heating.

(ii) Most candidates did not know why the lid was kept on for the first two minutes. A common misconception was to keep the heat in and raise the temperature. Other suggestions included to prevent the loss of water or to prevent oxygen from reacting with the contents of the crucible.

(iii) The most common correct explanation seen was that amount of water would be lower so the value **x** would be smaller. Candidates who did not explain why or did not refer to mass or moles/amounts in their answer did not gain credit. Some candidates used their results to link whether the sample had been heated to constant mass as the reason that **x** was/was not higher than expected, ignoring the candidate's suggestion given in the question.

Question 2

Most candidates appeared to be well practised in titration exercises as they displayed their results correctly and achieved one or more accuracy marks. Some candidates were less successful at processing their results.

(a) Many candidates scored highly for the presentation of their titration results. Candidates should be reminded that the burette readings for the rough titration must be recorded either in the space provided or clearly labelled in the main titration table.

Column headings were good; however, some candidates used 'initial' rather than 'initial volume'. 'Amount' instead of 'volume' was also seen - candidates should be aware that 'amount' refers to moles. The best heading for the volume added is 'titre'.

Some candidates gave their initial reading as 50.00 cm^3 instead of using the scale engraved on the burette.

Most candidates recognised that the final titre needs to be concordant (within 0.10 cm^3 of another) and most gained at least partial credit for accuracy.

(b) Most candidates calculated their mean value correctly, clearly showing their working. Only titres within 0.20 cm^3 should be used to calculate the mean and it should be correctly rounded to 2 dp.

(c) (i) Many candidates used 3.48 × $^{(b)}/_{1000}$) as their final answer and gained partial credit as the question asks for 'amount of $KMnO_4$'. Some candidates gave their final answer to 2 sf even though the descriptors of the reactants were to 3 or 4 sf and the apparatus used was calibrated to this level. Occasionally, instead of their value for **(b)**, some candidates used 25.0.

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

(iii) While many candidates correctly used their answers to **(c)(i)** and the stoichiometry from **(c)(ii)**, fewer completed the calculation as the factor of 1000/25 was omitted. Some candidates ignored their titration results and used the mass of hydrated iron(II) sulfate given in the introduction and the M_r of anhydrous iron(II) sulfate to calculate moles and hence concentration. Some candidates could not access the mark as they gave their answer to 2 sf.

(iv) There were three main ways of calculating the correct answer, using **(c)(iii)** or using **(c)(i)** and the method outlined in the mark scheme; both of which were credited. The third approach was to use **(c)(iii)** to calculate the mass of iron(II) sulfate and mass of water in the original 30 g sample, then calculate the amount of each and find the ratio, **y** = $n(H_2O)/n(FeSO_4)$. A minority of candidates gained full credit, but many gained partial credit by showing correct working.

(d) Some candidates recognised that sulfuric acid was in excess so gained credit. A few of these went on to show this was true by calculation. Far more candidates agreed with the student with the most frequent incorrect response being linked to the relative uncertainties in measurement. Some candidates claimed the sulfuric acid acted as a catalyst so disregarded their answer in **(c)(ii)**.

(e) Many candidates concluded that **y** will be greater, most explaining that the titre would be lower or the amount of Fe^{2+} would be lower, though all answers given in the mark scheme were seen. Some candidates did not give quantities in their answer, stating there is less Fe^{2+} without referring to amount (moles) or concentration.

Question 3

Many candidates would have benefited from reading the introductory information given in the question thoroughly. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, adding a solid to a solution and calling it a precipitate is incorrect. 'Gas released' is not an observation and is not credited in place of 'effervescence'.

Greater preparation of candidates for qualitative analysis questions need not be costly for centres. Teachers could demonstrate reactions either by scaling up the quantities used or by using a flexi camera and screen to make the reaction visible to a class and by using the correct terminology during the demonstration.

(a) (i) Almost all candidates gained partial credit usually for noting effervescence or fizzing in Tests 1 and 3. Those gaining full credit clearly tested for and identified hydrogen gas. Common errors were reporting contradictory gas tests, describing the initial precipitate in Test 2 as red-brown, not noting the increase in temperature during either of the reactions in Tests 2 and 3, and describing the fading of the initial colour of solution in Tests 1 and 2 as becoming 'clear' or 'transparent' instead of colourless.

(ii) Most candidates noted the white precipitate when aqueous ammonia was added to **FB 6**. However, fewer candidates described the precipitate dissolving when adding the reagent to excess.

(iii) A minority of candidates gained credit for identifying **FB 5** as Zn. Use of the Qualitative analysis notes on page 10 of the Question paper and the formation of a white precipitate in **(a)(ii)** alerted candidates to disregard iron(II) and chromium(III) compounds. These compounds were frequently suggested. The formation of hydrogen in **(a)(i)** Test 3 suggested **FB 5** was a metal.

(iv) A minority of candidates gave very good answers to this question by describing the oxidation of zinc and/or the reduction of copper ions with correct changes in oxidation numbers or electron transfer. Many candidates did not answer the question as:

- they referred to a different test from Test 2,
- only stated that zinc was oxidised and copper reduced,

- they repeated their observations of colour change and/or formation of precipitate.

(v) Few candidates gave a correct answer. NH_3 was commonly seen instead of the expected $OH^-(aq)$. Not all of those giving the correct species were awarded credit as some candidates omitted state symbols.

(b) (i) The most frequently credited answers involved the colour changes of **FB 7** on heating and cooling. Some candidates noted the condensation formed on gentle heating and some tested the gas evolved using limewater. Of the latter, far more described the resulting mixture as 'milky' or 'cloudy' than noted the formation of a white precipitate.

(ii) Some candidates merely reiterated testing the gas formed on heating the solid with limewater rather than carry out a further test. Many candidates added aqueous barium chloride or barium nitrate to **FB 7**, sometimes followed by an acid, which was not always named, and concluded SO_4^{2-} or $S_2O_3^{2-}$ was present. Few of those adding a dilute acid after the aqueous barium salt noted effervescence.

CHEMISTRY

Paper 9701/37
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- clearly cross out and replace any work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were usually provided by centres. These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out the experiments using the same solutions, solid samples and equipment as the candidates so that supervisor / candidate results and observations can be compared and the quality of candidates' practical work be assessed fairly. Supervisors should ensure that more than one titration is carried out and that their results are concordant. It is advisable that the best practical chemist in the centre carries out the experiments. Centres should provide results for each laboratory and practical session.

Issues with supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issues have already been communicated to Cambridge I prior to the examination period.

Many candidates found the questions challenging. The recording and presentation of results varied significantly. **Question 3(a)(i)** required candidates to devise their own tests. Candidates should make use of the qualitative analysis notes provided when selecting and describing chemical tests. In **Question 3(a)(i)** and **3(c)**, use of the term 'precipitate' was often incorrect as it was used to describe an insoluble solid added to a solution. A precipitate may be formed only when two solutions are mixed.

Comments on specific questions

Question 1

(a) Candidates were prepared well for this titration experiment. Candidates should record their burette readings for their rough titration and then carry out at least two accurate titrations.

Candidates are encouraged to present their table of results as 'FIT' – Final reading / volume, Initial reading / volume, Titre. Each heading should have correctly displayed units / cm^3, in cm^3 or (cm^3), not ml.

As a burette is accurate to 0.05 cm^3, results should be recorded to either #.#5 or #.#0 cm^3. This does not apply to the titre.

The titration should be repeated until a result is obtained that is within 0.10 cm^3 of another result.

Most reported titrations were accurate when compared to those of the supervisor.

(b) The values selected to calculate a mean titre should be within 0.20 cm^3. Some candidates selected results outside this range and occasionally included the rough titre, which should not be used.

(c) (i) Many candidates were awarded this significant figure mark which required the answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to be given to 3–4 significant figures. Common errors included incorrectly calculating an answer of 90 for **(c)(iv)**. Presentation of results in standard form should be encouraged. It was clear that candidates giving an example answer of 5.00×10^{-2} were much more likely to give an answer to the required number of significant figures rather than presented as 0.0500 where rounding to 0.05 and hence only one significant figure was seen.

(ii) This was answered well. Some candidates did not covert the titre to dm^3.

(iii) The majority of candidates were able to apply the correct mole ratio of 2.5 although a small number of candidates multiplied by 5, or by 2/5.

(iv) This question asked for the calculation of the relative molecular mass, M_r, of the ethanedioic acid in **FA 1**. On page 2 of the question paper, the identity of **FA 1** is given as aqueous ethanedioic acid, $(COOH)_2 \bullet \mathbf{x}H_2O$. A_r values cannot be used to calculate the M_r, as the value of **x** is not known at this stage. Despite this, 90.(0) was often seen as a final answer. The M_r should be calculated by using the mass of **FA 1** in 1 dm^3 (6.20 g) and dividing this by the concentration of **FA 1** calculated in **(c)(iii)**.

(v) Calculation of the M_r of anhydrous ethanedioic acid $(COOH)_2$ (90) *was* required. This value should be subtracted from **(c)(iv)**, divided by 18 and the answer given as an integer. Some candidates did the calculation correctly but did not round correctly or did not give the answer as an integer. It was possible to re-start this calculation using data from **(c)(iii)** rather than **(c)(iv)** and some candidates provided detailed correct working to show how their answer had been obtained, albeit by a more challenging route.

(d) Ethanedioic acid is a reactant, therefore suggesting that the **FA 3** (sulfuric acid) is added to acidify the reaction / solution is not precise enough. **FA 3** is acting as the source of the H^+ ions in the reaction equation. Incorrect answers included the **FA 3** acting as a catalyst or as a buffer.

Question 2

(a) Many candidates gave accurate headings in their table. Candidates should refer directly to the method and the measurements they were asked to take when writing their headings. Common errors included reference to the solid after heating as '**FA 4**' (at this point it had undergone decomposition and was no longer **FA 4**) or headings that did not allow the two masses after heating to be clearly distinguished. Some candidates did not follow the instructions and only heated the crucible and contents once.

Marks **I** and **II** were unavailable to candidates that only heated the solid once. Many candidates were not awarded mark **II** due to the difference in masses between 1st and 2nd heating being too great.

Most candidates used a mass of **FA 4** within an acceptable range. Many candidates confused 'mass of **FA 4** used' with the change in mass of the solid on heating, i.e. the mass of water lost. The mass of **FA 4** used is the mass of **FA 4** added to the crucible initially.

Most candidates were awarded both quality marks for this question.

(b) (i) Many candidates were able to use the Periodic Table to calculate the M_r of $ZnSO_4$ and hence to calculate moles of residue. In both parts of the question, candidates could gain credit by using incorrectly calculated masses in the table in **(a)**.

(ii) Candidates were required to show their working; to produce an expression and evaluate it as an integer. Some candidates were able to recognise that **y** should be calculated from the ratio of the moles of water : moles of residue from **(b)(i)**. Other (more complex) expressions using a similar calculation to that performed in **Question 1** were equally valid. A small number of candidates gave an incorrect expression but were able to obtain partial credit for correctly evaluating it. Some candidates found this question challenging. Centres are encouraged to practise this experiment and the associated calculations.

(c) The most common correct answers involved the decomposition of ethanedioic acid or evaporation. Some candidates noted that the decomposition of ethanedioic acid would also produce carbon dioxide and therefore thermal decomposition is not a valid technique. Incorrect answers often referred to percentage error issues or did not understand the implications of ethanedioic acid being a hydrated organic compound rather than the hydrated inorganic salt in **Question 2**.

Question 3

(a) (i) This question proved very challenging with few candidates obtaining full credit. The question required candidates to devise a series of tests to indicate whether the following three were present in **FA 5:** zinc ions, sulfate ions and water of crystallisation.

Some candidates were able to show that water of crystallisation was present by gently heating the solid in a hard-glass test-tube and observing water vapour, steam or condensation. Some candidates attempted to prove that water of crystallisation was present by heating the sample and demonstrating mass loss. This is not a qualitative test to show that water of crystallisation is present as the mass loss could be caused by a different decomposition product.

Tests for zinc ions and sulfate ions, as given in the qualitative analysis notes, rely on the formation and solubility of white precipitates. **FA 5** was supplied as a white solid. The formation of a white precipitate cannot be judged by adding a white solid to a reagent. The required tests should have been carried out by initially forming an aqueous solution of **FA 5** by dissolving the solid in water. It was common to see this stage omitted. The results of tests with solid **FA 5** added to NaOH(aq), NH_3(aq) or aqueous barium nitrate / chloride were not valid. Candidates reporting a white precipitate, soluble in excess alkali incorrectly concluded that zinc ions were present. Their observation was an excess of solid **FA 5** dissolving in the alkali. Candidates who made a solution of **FA 5** were able to observe a white precipitate with NH_3(aq) (or NaOH(aq)) that was insoluble in excess alkali and correctly conclude that **FA 5** did not contain zinc ions.

Similarly, a solution of **FA 5** should have been used when testing for sulfate ions. Most candidates were able to identify a white precipitate with aqueous barium nitrate or barium chloride. The guidance on page 7 of the question paper states that 'where reagents are selected for use in a test, the name or correct formula of the element or compound should be given'. Despite this many errors were observed including writing the barium reagent as Ba^{2+} and giving the formula of barium nitrate as $BaNO_3$ or barium chloride as $BaCl$. When adding a dilute strong acid, some candidates were able to use dilute hydrochloric or nitric acid and show that the white precipitate did not dissolve, identifying the ion as sulfate rather than sulfite. Common errors included missing out this test, not specifying which dilute strong acid was used or using sulfuric acid which invalidates the test by adding sulfate ions. Some candidates used acidified $KMnO_4$(aq) as an alternative reagent which was acceptable provided a precise description of the test was given - the $KMnO_4$(aq) should remain purple or not be decolourised rather than ‘no change’.

(ii) This question was dependent on the tests in **(a)(i)**. The question indicated that candidates should complete the table using ticks and crosses. Some candidates only used ticks and left one or more boxes blank.

(b) (i) Observations on heating **FA 6** were often not recorded well. When carrying out an unfamiliar test, candidates should observe the initial and final appearance. Oxygen was produced when heating the solid. Many candidates were able to observe the gas relighting a glowing splint. Some candidates incorrectly identified ammonia or did not test the gas.

(ii) Most candidates recorded shades of purple or blue-black here suggesting that **FA 6** had not been heated enough in **(b)(i)**. Some candidates were able to observe the dark green solution produced.

(c) (i) This question required candidates to carry out seven tests to identify the common metal present in **FA 7**, **FA 8** and **FA 9**. This was done well. Where gas tests were carried out, oxygen was usually positively identified (although some candidates didn't record any gas tests at all). The colour changes for **FA 7** were often clearly identified.

Many candidates correctly identified 'no change' for **FA 8, Test 1 and 3**. The 'no change' for **FA 9 Test 2** was less frequently seen, with many candidates recording a black solution or precipitate here.

(ii) An off-white precipitate rapidly turning brown on standing (**FA 8 Test 2**) is listed in the qualitative analysis notes as Mn^{2+}. This showed that the common metal was Mn.

Many candidates correctly identified manganese or Mn. Some candidates gave their answer as Mn^{2+} which was correct for **FA 8**, but not **FA 6/7** or **FA 9**. The most common incorrect answer was Iron.

(iii) Fewer candidates could give the correct oxidation states after stating that the metal was Mn. The dark purple colouration of **FA 7** suggested potassium manganate(VII) and this solution was clearly an oxidising agent in **Test 3**. Candidates had previously used the same solution, labelled as **FA 2**, in the titration in **Question 1**.

CHEMISTRY

Paper 9701/38
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- follow the instructions in the method
- present results of quantitative work clearly, showing the precision of the apparatus used and appropriate units in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work
- cross out and replace work that is to be changed. Examiners must be able to read answers clearly with no ambiguity.

General comments

Supervisor results for both the quantitative and qualitative tasks were provided by many centres. These results are used when awarding accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**.

Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that Supervisor/candidate results and observations can be compared and the quality of candidates' practical work assessed fairly. It is advisable that the best practical chemist in the centre carries out the experiments.

Issues with the supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issue has already been communicated to Cambridge prior to the examination.

Many candidates found the qualitative analysis question more demanding. Almost all the candidates were able to complete the paper within the time allowed.

Comments on specific questions

Question 1

For almost all centres, this proved a reliable experiment with most Supervisors and candidates producing a mass ratio within the expected range. In cases where the Supervisor's value was outside the range, the candidates were usually within the range of the theoretical value.

(a) Many candidates found this question challenging and missed out on full marks. To improve future performance, please keep the following common pitfall in mind:

- ensure you distinguish between the starting material (**FB 1**) and the residue remaining in the crucible after heating,
- remember to record all required measurements, including the final 4th balance reading,

- it is important to list all calculated values; many candidates omitted the "mass lost",
- take care to correctly identify results, as some candidates confused the "mass lost" with the "residue" remaining in the crucible.

Other than the candidates who recorded just one mass of crucible and residue after heating, most candidates recorded two masses within the tolerance of +0.02 g and –0.05 g between the 1st and 2nd weighings after heating and reheating.

Candidates occasionally lost one mark due to calculation errors in subtractions. However, the most frequent issue preventing candidates from earning this mark was incomplete recording of all three required mass calculations. A few candidates had the value for **FB 1** outside range specified.

Many candidates gained full credit for accuracy in this question; only a few produced results that were outside the accepted range for the mass ratio.

Centres should be encouraged to have enough 2 decimal place (dp) balances for their candidates; 3 dp balances appeared to cause more errors and using them is more time consuming.

(b) (i) Most candidates successfully calculated the amount of water lost using their value for mass lost. Some candidates rounded their answer to one significant figure (sf), usually when their calculated value was 0.05(00).

(ii) Many candidates correctly calculated the amount of **FB 1**, but some used 32 instead of 32.1 for the A_r of sulfur.

(iii) The most common errors were not giving the final answer as an integer and incorrect rounding.

(c) (i) The question asked for the difference in appearance of **FB 1** and the residue; only a few candidates described the appearance of the solid before heating.

(ii) Most candidates did not know why the lid was kept on for the first two minutes. A common misconception was to keep the heat in and raise the temperature. Other suggestions included to prevent the loss of water or to prevent oxygen from reacting with the contents of the crucible.

(iii) The most common correct explanation seen was that amount of water would be lower so the value **x** would be smaller. Candidates who did not explain why or did not refer to mass or moles/amounts in their answer did not gain credit. Some candidates used their results to link whether the sample had been heated to constant mass as the reason that **x** was/was not higher than expected, ignoring the candidate's suggestion given in the question.

Question 2

Most candidates appeared to be well practised in titration exercises as they displayed their results correctly and achieved one or more accuracy marks. Some candidates were less successful at processing their results.

(a) Many candidates scored highly for the presentation of their titration results. Candidates should be reminded that the burette readings for the rough titration must be recorded either in the space provided or clearly labelled in the main titration table.

Column headings were good; however, some candidates used 'initial' rather than 'initial volume'. 'Amount' instead of 'volume' was also seen - candidates should be aware that 'amount' refers to moles. The best heading for the volume added is 'titre'.

Some candidates gave their initial reading as 50.00 cm^3 instead of using the scale engraved on the burette.

Most candidates recognised that the final titre needs to be concordant (within 0.10 cm^3 of another) and most gained at least partial credit for accuracy.

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

(iii) While many candidates correctly used their answers to **(c)(i)** and the stoichiometry from **(c)(ii)**, fewer completed the calculation as the factor of 1000/25 was omitted. Some candidates ignored their titration results and used the mass of hydrated iron(II) sulfate given in the introduction and the M_r of anhydrous iron(II) sulfate to calculate moles and hence concentration. Some candidates could not access the mark as they gave their answer to 2 sf.

(iv) There were three main ways of calculating the correct answer, using **(c)(iii)** or using **(c)(i)** and the method outlined in the mark scheme; both of which were credited. The third approach was to use **(c)(iii)** to calculate the mass of iron(II) sulfate and mass of water in the original 30 g sample, then calculate the amount of each and find the ratio, **y** = $n(H_2O)/n(FeSO_4)$. A minority of candidates gained full credit, but many gained partial credit by showing correct working.

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Question 3

Many candidates would have benefited from reading the introductory information given in the question thoroughly. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, adding a solid to a solution and calling it a precipitate is incorrect. 'Gas released' is not an observation and is not credited in place of 'effervescence'.

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(ii) Most candidates noted the white precipitate when aqueous ammonia was added to **FB 6**. However, fewer candidates described the precipitate dissolving when adding the reagent to excess.

(iii) A minority of candidates gained credit for identifying **FB 5** as Zn. Use of the Qualitative analysis notes on page 10 of the Question paper and the formation of a white precipitate in **(a)(ii)** alerted candidates to disregard iron(II) and chromium(III) compounds. These compounds were frequently suggested. The formation of hydrogen in **(a)(i)** Test 3 suggested **FB 5** was a metal.

(iv) A minority of candidates gave very good answers to this question by describing the oxidation of zinc and/or the reduction of copper ions with correct changes in oxidation numbers or electron transfer. Many candidates did not answer the question as:

- they referred to a different test from Test 2,
- only stated that zinc was oxidised and copper reduced,

- they repeated their observations of colour change and/or formation of precipitate.

(v) Few candidates gave a correct answer. NH_3 was commonly seen instead of the expected $OH^-(aq)$. Not all of those giving the correct species were awarded credit as some candidates omitted state symbols.

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(ii) Some candidates merely reiterated testing the gas formed on heating the solid with limewater rather than carry out a further test. Many candidates added aqueous barium chloride or barium nitrate to **FB 7**, sometimes followed by an acid, which was not always named, and concluded SO_4^{2-} or $S_2O_3^{2-}$ was present. Few of those adding a dilute acid after the aqueous barium salt noted effervescence.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

There were too few candidates for a meaningful report to be produced.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

- Calculations answers should generally be given to a minimum of 2 or 3 significant figures. In a calculation that involves two or more stages, rounding should only be done at the final stage.
- Candidates found it difficult to interpret structural formulae correctly. This is a key skill in chemistry and should be extensively practiced.
- Clarity of handwriting was an issue for some candidates. When key terms like 'exothermic' or 'endothermic', or numerals such as 1 and 2 or 4 and 9, are indistinguishable, marks cannot be awarded. Candidates are encouraged to ensure their responses are legible to avoid losing credit.
- Candidates who wish to change an answer must cross out their original answer completely. If there is insufficient space to write a replacement answer, there are blank pages on the question paper which can be used. A comment such as 'continued on page 2' is helpful.

General comments

The correct following of convention is needed when writing the formulae of substances. $KMnO_4$ written as $KMNO_4$ or even $KmNO_4$ will not gain credit.

When the name of an organic substance is asked for candidates must apply the accepted rules.

Marks were lost on many scripts due to the use of loose descriptions rather than precise language. The word 'it' should be avoided wherever possible. In organic chemistry, the expression 'the bond' is unhelpful; an expression such as 'the O–H' bond should always be used.

When a comparison of bonding or attractive forces is required, simple comparative words such as 'stronger' and 'weaker' should be used.

Comments on specific questions

Question 1

(a) A significant number of unbalanced equations were seen.

(b) Statements such as 'the nitrate is more polarised by Mg^{2+}' did not contribute to the second mark. Statements such as 'the nitrate **ion** is more polarised by Mg^{2+}' or 'the **anion** is more polarised by Mg^{2+}' were awarded this mark.

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

(ii) Many candidates showed correct knowledge and wrote a clear explanation.

Question 2

(a) (i) This mark was not often awarded.

(ii) Many candidates found this question to be one of the most difficult questions on the paper. Common errors included:

- Nitrogen or oxygen atoms with more than eight electrons in their outer shells.
- The hydrogen atom bonded to the nitrogen atom in HNO_2. It was stated in the question that this hydrogen atom is bonded to one of the oxygen atoms.

(iii) This question discriminated well.

(b) This question was answered very well.

(c) Many candidates believed that the graph would show a constant half-life because the reaction is first order with respect to $[NO_2]$. The half-life is not constant because the reaction is also first order with respect to $[CH_3CHO]$. The reaction is overall second order, and such reactions do not have a constant half-life.

(d) This question was answered very well.

(e) Some candidates gave very brief answers such as:

- adsorption
- bonds weakened
- desorption.

This should be avoided. If candidates wish to use a bulleted list this is much better:

- adsorption of reactants onto the catalyst surface
- bonds weakened within reactant molecules, followed by reaction to form products
- desorption of products from the catalyst surface.

Question 3

(a) (i) This question discriminated well. Many candidates did not specifically state that the members of a conjugate acid–base pair differ by one proton.

(ii) This question discriminated well.

(b) (i) Most candidates answered this question well. Many candidates have an excellent grasp of the examined calculations.

(ii) Most candidates answered this well.

(iii) The correct answer was often seen. A significant number of candidates tried to use a K_a calculation.

(iv) This question discriminated well. Most candidates answered the question correctly to some degree. Some candidates believed that a weaker acid has a greater K_a value.

(c) (i) Candidates often found both parts of **(c)** very difficult. More answers in **(c)(i)** began with H_2SO_4 than with NaOH. Those candidates who chose NaOH usually wrote the correct equation.

(ii) Those candidates who chose H_2SO_4 often found the explanation difficult. The question was looking for recognition that solution **D** does not contain a weak base. Sensible answers which included accurate and relevant chemistry were awarded credit.

(d) (i) Most candidates answered this well.

(ii) Most candidates answered this well. Expressions such as $(Mn)(OH)^2$ and $(Mn^{2+})(2OH^-)^2$ were not awarded the first mark. The mark for units was usually awarded.

(iii) This question discriminated well. The most common error was to not realise that the concentration of OH^- in the saturated solution is twice the concentration of Mn^{2+}.

Question 4

(a) A common error was to state that gaseous atoms are formed from a mole of element. This does not work for elements such as O_2 and N_2, where one mole of the element contains two moles of atoms.

(b) Answers that began 'The energy change when one electron is added to one mole of . . .' were unsufficient. Answers that began 'The energy change when one electron is added to **each** atom in one mole of . . .' usually went on to secure the mark. Other approaches, such as 'The energy change when one mole of gaseous atoms gains one mole of electrons' were also acceptable.

(c) This question discriminated well. Many candidates referred to the difference in the **ionic** radii of chlorine and iodine; this did not gain credit since chloride ions and iodide ions are not the particles that are gaining electrons. It is the difference in **atomic** radii that matters.

(d) It was rare to see both marks awarded for this question. The most common errors included –122 and +122 from the incorrect calculations 364 – 486 and 486 – 364.

Question 5

(a) (i) This question was often answered well. The most common incorrect answers included electrons in the 4s sub-shell.

(ii) This question discriminated well.

(iii) This question discriminated well. The meaning of 'state' was not always understood.

(iv) Some candidates did not know that $[CoCl_4]^{2-}$ is formed and so were unable to write a correct equation. Many candidates submitted answers in which CO, rather than Co, was used as the symbol for cobalt. Precision in writing symbols is important and should be strongly encouraged.

(v) This mark was usually awarded. Answers such as 'acid–base' were often seen. The water ligands are being replaced here, not deprotonated.

(vi) This question discriminated well. Many unbalanced equations were seen.

(b) (i) Some candidates used E_{cell} instead of $E^{\ominus}$ and so lost one or both marks. Other candidates had errors involving their use of addition signs or multiplication signs in their equations, e.g.

- $E = E^{\ominus} \times (0.059/z)\log((ox)/(red))$
- $E = E^{\ominus} + (0.059/z) + \log((ox)/(red))$.

(ii) This question discriminated well. 1.61V was a common incorrect answer.

(iii) This question was answered well by many candidates. Errors included using both Co^{2+} and $Cr_2O_7^{2-}$ on the left of the equation and equations that were reversed but otherwise correct.

(iv) This question was answered well. In questions about electrochemical cells, it is advisable to avoid use of 'anode' and 'cathode'. In this question the electrodes should have been identified as Co^{2+}/Co and $Cr_2O_7^{2-}/Cr^{3+}$ instead.

(c) Many correct answers to this question were seen. Candidates who made one error, for example omitting the '2' to show that each Co^{2+} ion gains two electrons, often gained two of the three marks. This was because they showed working and explained their calculation clearly, making it possible to award two marks for their otherwise correct method.

Question 6

(a) (i) Many candidates ignored the information that this complex contains nickel **atoms** and submitted answers such as $[Ni(CO)_4]^{2+}$.

(ii) Some candidates believed that ethanedioate ions were *en*, 1, 2-diaminoethane. Although one mark was still possible after this error, it was not often awarded. Candidates who knew that the formula of ethanedioate is $C_2O_4^{2-}$ were usually awarded one mark or both marks.

(iii) The correct answer was often seen. Many candidates who were unsuccessful in **(a)(ii)** were able to secure this mark, likely by reasoning that:

- $Ni(CO)_4$ cannot show isomerism.
- an octahedral complex containing only one type of ligand can show optical isomerism but is unlikely to show geometrical isomerism.

(b) (i) Most candidates answered this well. It should be noted that candidates had to refer to the structure of CH_3NH_2 to be awarded the mark. Answers such as 'CH_3NH_2 has only one lone pair of electrons which is on the nitrogen atom' were good to see. Use of 'it' should be avoided as it could refer to either 'monodentate ligand' or to CH_3NH_2.

(ii) The correct answer was often seen.

(iii) This question discriminated well. Common errors include
- an expression written the wrong way up
- $(Cd(CH_3NH_2)_4)^{2+}$ used in place of $[[Cd(CH_3NH_2)_4]^{2+}]$ on the top of the expression.

Question 7

(a) Many candidates found difficulty in interpreting the structural formulae for **P**, **Q**, **R**, **S**, **T**, **U**, and **V**; however, a significant number of precise and accurate responses were still provided.

(b) (i) This question discriminated well.

(ii) This question discriminated well. CH_3I was sometimes given incorrectly as the formula of iodoform.

(c) (i) This question discriminated well.

(ii) This question discriminated well.

(iii) The correct answer was often seen. Some candidates could not name the splitting pattern.

(iv) The correct answer was often seen.

(d) This question discriminated well.

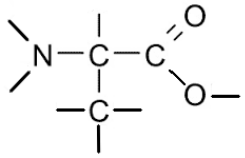
Question 8

(a) The correct definition was known by many candidates. It should be noted that any definition of isoelectric point should state that it is a **pH value**.

(b) This question discriminated well. Many candidates overlooked the non-basic nature of the amide group.

A very small number of candidates were still using the 'implied hydrogen' convention. This convention involves drawing a C–H bond, or an N–H bond, or an O–H bond as a line, without writing the H on the end of it. This should not be done in an examination as it will always lose marks.

An example of 'implied hydrogen', representing the amino acid alanine, is shown below.



(c) Many candidates knew that the –COOH groups are reduced to $–CH_2OH$ groups. Fewer candidates knew that the $–CONH_2$ groups are reduced to $–CH_2NH_2$ groups.

(d) (i) Candidates had to show that each $SOCl_2$ molecule only reacts with one –COOH group to gain full credit.

(ii) Responses to this section were varied, with many candidates finding the concept challenging. The given molecular formula, and the information 'Each molecule of compound **G** has four amide groups' were intended to help candidates to reach the correct answer. Many candidates attempted a structure with four amide groups that fitted the formula, without reference to the structure of the reactants or the chemistry of the condensation reaction.

(e) Many candidates knew that a –COOH group reacts with hot NaOH(aq) to form a $–COO^-Na^+$ group. Fewer candidates knew that a $–CONH_2$ group also reacts with hot NaOH(aq) to form a $–COO^-Na^+$ group.

(f) Most candidates found this question to be very difficult. Many candidates were awarded at least one mark, and some excellent answers gaining full marks were also seen.

(g) (i) Precision was required here. The two optically active forms **rotate the plane** of plane polarised light by **the same angle**, but **in different directions**.

(ii) The correct answer was often seen.

Question 9

(a) Some excellent answers were seen but overall candidates found this question to be very difficult. Very few candidates could describe the different orbital overlaps that produce each type of bond. For example, the C–H σ bonds are produced by sp^2–s orbital overlap.

If candidates are not confident in their use of the symbols σ and π they should use the words sigma and pi.

(b) Most candidates answered this well.

(c) Many candidates submitted precise and accurate diagrams to show their understanding of the mechanism of electrophilic substitution. Therefore, three marks were often awarded.

(d) The correct answer was often seen.

(e) The correct answer was often seen.

(f) This question discriminated well.

(g) The correct answer was often seen.

(h) The first mark was often awarded for describing an alternative route that gave **Y** as its product. Commonly seen correct answers included 'perform step 3 before step 2'.

The second mark was awarded less frequently. Electron-withdrawing groups do not 'activate the 3,5-positions'. Since they are electron-withdrawing they are deactivating when electrophilic substitution is involved. A much better description is that electron-withdrawing groups are '3,5-directing'.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Answers to calculations should be given to a minimum of 2 or 3 significant figures (sf). In a calculation that involves two or more stages, the full number should be left on the calculator after each stage, then the final answer should be rounded to 3 sf.
- If a candidate wishes to change an answer, they must cross out their original answer completely and a new answer should be written. If there is insufficient space to write their replacement answer, blank pages on the question paper can be used. Any response that is not written in the given response space must be clearly labelled, such as 'see page 2'.

General comments

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

Both care and the correct following of convention are needed when writing the formulas of substances.

Working should be shown when answering questions involving calculations.

Comments on specific questions

Question 1

(a) (i) Many candidates gave the correct equation for the decomposition of strontium hydrogencarbonate. A common error was writing an equation with strontium oxide as one of the decomposition products, despite the question highlighting the products formed.

$$Sr(HCO_3)_2 \rightarrow SrO + 2CO_2 + H_2O$$

(ii) This question was well answered by most candidates. Many candidates gave a correct statement regarding increasing cation radius down Group 2. Decreasing polarisation of the carbonate anion was less frequently seen. Some candidates incorrectly suggested there was polarisation of the cation or that polarisation was caused by the anion. A few candidates incorrectly discussed the strength of the ionic bond increasing between anion and cation, rather than the C-O bond being less weakened.

(b) The trend and its explanation were well understood by most candidates. Some candidates, however, misunderstood the question and compared the solubility of the corresponding hydroxides in water instead of the fluorides in water. It was common to see a statement regarding increasing solubility due to ΔH_{latt} and ΔH_{hyd} becoming less exothermic and ΔH_{sol} becoming more exothermic down Group 2. The 'change in ΔH_{latt} is more' was less frequently seen.

(c) (i) This definition was well known. Common errors were to refer to gaseous atoms dissolving rather gaseous ions, or to give a definition of the enthalpy change of solution.

(ii) Most candidates gained partial credit for stating the main factors. Many candidates gave an incomplete explanation, either omitting the effect on the enthalpy change of hydration or how the attraction between the ion and water molecules was affected.

(d) Most candidates calculated the correct enthalpy change of solution. The most common error was an answer of +526 (not multiplying –505 by 2).

(e) (i) In the expression for K_{sp}, the most common error was the formula of the mercury ion being given as (Hg^{2+}) or (Hg^{+}). Some candidates did not include charges on the ions. Most candidates gained partial credit for the unit.

(ii) The K_{sp} was usually correctly calculated.

Question 2

(a) Most candidates answered this question well. Some candidates gave an incomplete answer just stating that orbitals were energetically accessible

(b) Most candidates answered this question well. Some candidates omitted 'metal' when referring to metal ion.

(c) (i) Candidates often gave the correct answer here.

(ii) This was well answered, and many candidates were awarded full credit. Common errors included stating that $Fe(H_2O)_4(OH)_2$ had a more negative E value, rather than $Fe(H_2O)_3(OH)_3$, and omitting an equation for this reaction.

(d) Many correct answers were seen for this question. Some common errors were:

- –161 (use of n=1)
- +322 (sign error normally in their original equation).

Question 3

(a) This was well known. Some candidates incorrectly stated the type of catalysis as 'heterozygous' and 'heterolytic'.

(b) (i) This question discriminated well and many responses lacked the necessary precision. Candidates were first expected to determine the order of reaction with respect to [I^-]. This value should then have been used, together with the remaining experimental data, to deduce the orders of reaction with respect to [H_2O_2] and [H^+]. Some candidates quoted data from experiment 1 and 2 and concluded that the order of reaction with respect to [I^-] and [H_2O_2] is the same, which was not sufficient. Some candidates omitted a rate equation in their answer.

(ii) This was generally answered well. Most candidates were awarded full credit.

(c) (i) Candidates often gave the correct answer here. A common error was just stating the half-lives were constant without calculating two half-lives.

(ii) The relationship $k = \ln 2 / t_{½}$ was well known and used correctly.

(d) Most candidates gave a correct answer. Some candidates only mentioned one of k or rate.

Question 4

(a) Full credit was often awarded. Common errors included:

- including the standard hydrogen electrode (SHE) as one of the electrodes
- omitting the description of standard conditions.

(b) (i) This was answered well. Many candidates were awarded full credit. Some common errors included:

- an incomplete circuit – commonly, the solution levels in the beakers not touching the salt bridge
- some incorrectly labelling of a solution as the half-cell, for example Cu/Cu^{2+}.

(ii) Most candidates identified that the charge carriers in the wire are electrons, however those in the solutions were less well known.

(iii) This question was answered well. Many candidates could recall the Nernst equation. Common errors included –0.80 (use of z = 1) and –0.74 (use of log(1 ÷ 0.25)).

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

(ii) Most candidates gave the correct answer.

(iii) Most candidates gave the correct answer.

Question 5

(a) This question was well answered. A common error was to state the total number of 3d electrons in Cu and Cu^{2+}, instead of the number of unpaired electrons.

(b) The splitting of five d orbitals in the isolated Cu^{2+} into three upper and two lower orbitals was well known. Many candidates did not show a higher energy of the d orbitals in the complex compared to the d orbitals in the isolated ion.

(c) This question discriminated well. A full explanation was required. Most candidates stated that transition elements exist in variable oxidation states. Partial answers such as 'has vacant d orbitals' did not gain credit.

(d) Some candidates omitted the brackets around CN.

(e) This question proved difficult for most candidates. Common errors included:

- drawing an incorrect square planar diagram
- drawing a tetrahedral diagram
- stating a bond angle of 90°.

(f) (i) This was well answered, and many candidates were awarded full credit. A common error was using the M_r of VO_3^- instead of V.

(ii) This equation was balanced correctly by many candidates.

Question 6

(a) (i) This question was answered well. The recall of the definition of a R_f value seemed better than that of retention time.

(ii) This question proved difficult for most candidates. A common error was stating Al_2O_3 or SiO_2 for the mobile phase for TLC and omitting 'non-volatile' for the stationary phase in gas/liquid chromatography.

(b) This question discriminated well. Many candidates commented on the distance travelled by **A**, rather than suggesting why in terms of relative solubility in the mobile phase or relative adsorption to the stationary phase.

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

(ii) This question proved difficult for many candidates. Most candidates identified that **Z** would observe a triplet and a quartet. However, many candidates incorrectly stated that a triplet would be observed with **Y** in addition to a singlet.

Question 7

(a) Many candidates gave a correct order of acidity and some good explanations were seen. Most candidates made a correct link between the electron-withdrawing group and the weakening of the O–H bond. Common errors included:

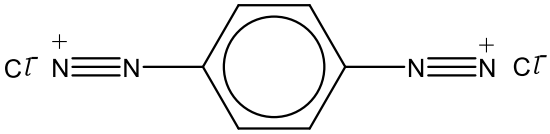
- stating that Br is more electronegative than C*l*
- omitting the electron-withdrawing properties of the C=O group.

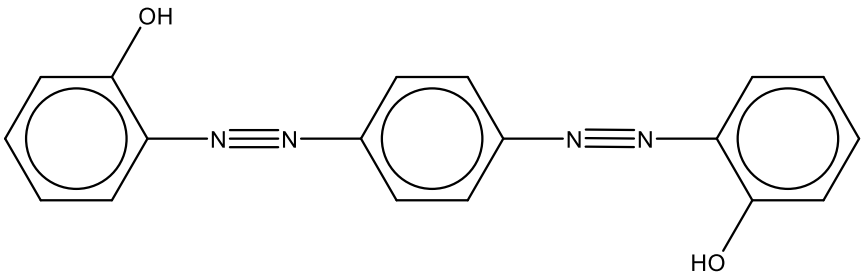
(b) Most candidates correctly identified benzoic acid. However, many found it difficult to identify CO_2 as the product from the oxidation of ethanedioic acid.

(c) (i) This question discriminated well. Many good answers were seen. Common errors were the inclusion of a trivalent carbon or an incorrect amide linkage, such as −COO−NH−.

(ii) The equation was well known by many candidates. A common error was stating O_2 as a product.

(d) (i) Many candidates found this a challenging question, which discriminated well. Common errors included placing the positive charge on the terminal N atoms for **V** and drawing N≡N bonds in **W**.





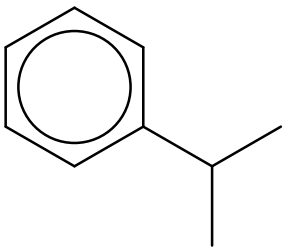
(ii) This was answered well. Common errors included omitting a temperature or the use of $NaNO_3/HNO_3$ instead of $NaNO_2/HNO_2$.

Question 8

(a) (i) Many candidates understood that the nitro group was electron withdrawing and therefore 3,5-directing. Some candidates stated that the nitro group was 1,3-directing which was not sufficient.

(ii) This question was answered well.

(b) (i) Many correct structures were seen. The most common error was alkylating the benzene ring, instead of acylating the ring.



(ii) Many candidates answered this question well. Common errors were:

- omission of a halogen carrier for reaction 1 and 2
- suggesting an ambiguous structure for these reactions, for example CH_3CH_3CHBr and $COClCH_3$.

(c) This question proved difficult for candidates, although some excellent answers were seen. The most common errors were:

- an incorrect observation for C_6H_5Br as a white precipitate
- omitting the effect on the C–Br bond strength.

(d) (i) This was answered well. Incorrect answers included 'electrophilic substitution' and 'hydrolysis'.

(ii) This question discriminated well. Some very good answers were seen. Common errors included:

- omitting the lone pair on the O in H_2O
- omitting the dipole for the C=O bond
- an incorrect intermediate structure
- the first curly arrow in the intermediate going from the O^- to the C atom instead of the C−O bond
- the second curly arrow in the intermediate starting at the C instead of the C−Br bond to the Br.

Question 9

(a) This question discriminated well. Stronger performing candidates often gave good explanations. Weaker performing candidates found the explanation challenging. Many candidates could link basicity to ability of the lone pair of electrons to accept a proton / form a coordinate bond to a proton. Points of note are:

- 'attract a proton' is **not** equivalent to 'accept a proton'
- the lack of basicity of an amide is due to the lone pair of electrons on the nitrogen atom being delocalised into the C=O group.

(b) (i) This question was answered well by many candidates. Common errors included $C_6H_5CH_2CH_2CN$ for **M** and $C_6H_5CH_2CH_2OH$ for **N**.

(ii) This question was answered well.

(c) This question was answered well. Carboxyl was a common error as the functional group.

(d) (i) This was found to be a challenging question. Candidates were asked to add three curly arrows to show how the ozonide ring structure was formed. It should be noted that two new bonds needed to be formed and one bond to be broken.

(ii) This question was found to be difficult. Many candidates incorrectly suggested a non-cyclic structure with two C=C bonds.

CHEMISTRY

Paper 9701/44
A Level Structured Questions

Key messages

- In organic reaction mechanisms, the start and end points of curly arrows are a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.
- Calculations should show working clearly and answers should be given to an appropriate number of significant figures.
- Questions requiring application of knowledge or explanation of phenomena require precise scientific language.
- When comparing the magnitude of negative energy changes, the terms more/less exothermic should be used.

General comments

Handwriting and calculation working was of a good standard and assisted in the marking of responses.

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

Comments on specific questions

Question 1

(a) A common error was omission of 'stable' ions.

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

(ii) This question was well answered.

(c) (i) This question was well answered. The colour of the $[CuCl_4]^{2-}$ complex should be stated as yellow.

(ii) The **d** sub-shell must be referred to when describing the splitting. Most candidates described electron promotion. The complementary wavelength being seen must be referred to in order to obtain full marks.

(d) (i) The answer space provided before the arrow required two species ($4NH_3 + 2H_2O$). Many candidates tried to combine the required atoms into one species to fit the space.

(ii) This question was well answered. HO_2 is not accepted as a ligand. Correct connectivity of monodentate ligands is desirable. Any incorrect formula of a ligand will not be credited.

(iii) Most candidates identified the correct isomer. Reference to dipoles was required for the mark. Polarity, partial charges or ion-dipoles were referred to by many candidates. These were not awarded credit.

(e) (i) Reference to **lone** pair of electrons is required when referring to denticity of ligands.

(ii) This question was well answered. Charges shown on ligands in the formula as part of working should be removed in the final answer. Candidates should be aware that the addition of two

tridentate ligands will give an octahedral complex and therefore all H_2O ligands should be removed from the final product.

(f) (i) Many candidates did not include all the required detail in this definition. Most candidates omitted reference to a solvent, or the constituent ions. Some candidates did not identify K_{stab} as an equilibrium constant.

(ii) This question was well answered.

(g) Candidates scoring all three marks here set out their working in a clear, logical manner and labelled all their values appropriately. It is preferred that candidates retain values in their calculator and use these unrounded values in subsequent steps in their working.

Question 2

(a) This question was well answered. When referring to negative energy changes and how they change down the group, the term 'less negative' should be used rather than 'decrease', which is unclear.

(b) (i) The question stated that the required equation was an equilibrium and therefore a reversible reaction arrow was required.

(ii) To obtain full marks, candidates needed to multiply their calculated value of *x* by 2 in the calculation of $[Ag^+]$.

(c) (i) This question was well answered. Some candidates attempted a calculation using the Henderson-Hasselbalch equation for buffers, which did not gain credit.

(ii) This question was well answered.

(d) (i) This question was well answered.

(ii) Many candidates found this question challenging. Repulsion between electrons was not credited, as this exists in the first electron affinity as well as the second electron affinity. Reference was required to the electron being **gained**. Many candidates omitted this, only referring to the repulsion between the negative ion and electron(s), which was unclear.

(iii) This question was well answered.

(iv) Most candidates were able to extract the required values from the table and to evaluate them correctly. Common errors included omission of the multipliers (x2) with Ag values and sign errors.

(e) Many candidates correctly identified the relative magnitudes of lattice enthalpy. Common errors included reference to atomic radius and identification of the copper ion in Cu_2S as Cu^{2+}.

Question 3

(a) This question was well answered. Some candidates continue to use 'measure of disorder', which gained no credit as a description of entropy. Good answers should include reference to the distribution of **energy** in the system.

(b) (i) This question was very well answered.

(ii) Most candidates were able to evaluate the values correctly. Common errors included omission of the multipliers and sign errors.

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

(ii) Many candidates accessed all the marks in this question. Calculation of $\Delta S^\ominus$ from the gradient of the line was done well. The most common errors were sign errors or omission of conversion into $J\ K^{-1}\ mol^{-1}$.

Many candidates chose to calculate $\Delta H^{\ominus}$ and then use this value with their $\Delta S^{\ominus}$ to determine T. This was an acceptable method, but a more accurate answer is obtained by reading the x-axis intercept from the graph provided.
Many candidates chose to calculate $\Delta H^{\ominus}$ from their calculated $\Delta S^{\ominus}$ and T read from the graph. This was an acceptable method, but a quicker method is to extend the line provided to the y-axis and read off the intercept value.

Question 4

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

(ii) This question was very well answered.

(iii) This question was very well answered.

(iv) Many candidates found this question challenging. To obtain the mark, candidates needed to recognise that collisions involving three or more particles are highly unlikely, or to use the stoichiometry of the overall equation and compare this with the orders in the rate equation.

(v) Common errors in this question included steps involving more than two species. Many candidates scored one mark for the final step.

(vi) Many candidates incorrectly identified N_2O as a catalyst, rather than as an intermediate.

(b) This question was very well answered.

(c) (i) This question was well answered. Correct terminology is important. Homolytic and homologous are similar words but are not acceptable as alternatives as they have a different chemical meaning.

(ii) Many candidates applied their knowledge of the role of Fe^{3+} as a catalyst in this reaction to the use of Co^{3+}. Some candidates used Fe^{3+} in place of Co^{3+}. A common error was to start the first equation with Co^{2+} reacting with I^- and to have Co^{3+} reacting with $S_2O_8^{2-}$ in the second step – this did not gain any credit. Candidates should make sure that equations are always balanced, including for charge.

(iii) This question discriminated well. Many candidates referred to a higher activation energy or to the effect of a catalyst in lowering activation energy. The reason for the higher activation energy – the **repulsion** between negative ions – was often omitted.

Question 5

(a) Most candidates correctly identified the bond angle and hybridisation present in benzene. Descriptions of the shape of benzene often omitted the planar nature around the C atoms. Many candidates did not refer to the orbitals or the direction of overlap involved in the formation of σ and π bonds in benzene.

(b) (i) Reagents for reaction 5 were well known. Reagents for reaction 6 commonly showed an incorrect structural formula for the acyl chloride. Candidates should check that their species contains an appropriate number of carbon atoms.

(ii) This question was very well answered.

(c) (i) Most candidates identified the 2,4-directing nature of the ethyl group. To obtain the mark, candidates must link the electron donating nature of the alkyl group to its directing effect.

(ii) This question was well answered.

(iii) The curly arrow from the π-electron ring should be shown coming from the circle representing the delocalised electrons (not from inside the circle, or from the lines of the hexagon) and should attack the C^+ atom in the $^+CH_2CH_3$ electrophile.

The 'open' end of the horseshoe shape in the Wheland intermediate should point toward the substituted C atom and the shape should cover the remaining 5 C atoms in the delocalised system. Many candidates had the open end covering more than one C atom in the ring.

(iv) This question was very well answered.

Question 6

(a) This question was very well answered.

(b) (i) Many candidates did not correctly identify both reaction types.

(ii) Many candidates found this question challenging. Few candidates identified the hydrolysis of the primary amide in reaction 7. In reaction 8, a common error was to react the amide group. In reaction 9, a common error was to react only one of the amide or nitrile.

(c) (i) Most candidates identified the number of carbon environments.

(ii) This question was well answered. A common error was made in proton environment **b**, identifying the splitting as a triplet or quartet or giving an incorrect chemical shift range.

Question 7

(a) Most candidates identified the correct order of acidity. Most candidates correctly linked acidity to strength of the O-H bond. Candidates should make this link clear by stating it in their answer. Explanations were generally good. Some candidates confused phenylmethanol and 4-methylphenol in terms of the effect of electron donating alkyl groups.

(b) This question discriminated well. The most common error was to produce H^+ ions rather than H_2. Some candidates did not correctly balance the organic species.

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

(ii) Many candidates omitted the type of polymerisation taking place in reaction 11.

(iii) This question was well answered. Candidates must ensure that they do not include additional atoms in the repeat unit.

Question 8

(a) This question discriminated well. Candidates who knew the relative reactivity of the two species were often able to explain their answers well. A common error was to confuse the ease of hydrolysis with the reactivity of the ring in chlorobenzene.

(b) (i) Candidates must be careful in the spelling and accurate naming of functional groups. Cyanide and peptide were commonly seen for nitrile and amide, respectively, and gained no credit. Alkyl groups are not classified as functional groups and should not be included in an answer.

(ii) Most candidates identified 3 chiral centres and gave this as their answer. Candidates need to understand the relationship number of optical isomers = 2^n, where n is the number of chiral carbon atoms.

(iii) Few correct answers were seen. Most candidates answered in terms of biological activity (efficacy of drug or minimising side-effects), which was expressly ruled out in the stem. Candidates must carefully read the stem of the question to determine what answers will gain credit.

(c) Most candidates correctly hydrolysed the amide link. Many candidates correctly hydrolysed the cyclic ester link. Most candidates did not hydrolyse the nitrile group. Candidates should use the number of marks available in a question to help identify the number of groups reacting.

(d) (i) This question was very well answered.

(ii) This question discriminated well. Many candidates responded in terms of polarity. Retention time in the gas chromatograph is related to the attraction or intermolecular forces between the molecule and the stationary phase, where greater attraction leads to longer retention time.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

There were too few candidates for a meaningful report to be produced.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- When plotting the points on the grid in **Fig. 2.2**, **Question 2(c)**, some candidates moved the points to the nearest horizontal grid line which is not acceptable.

- Diagrams should be drawn in two dimensions as 3-D diagrams often hide key parts such as the positioning of the filter paper within a filter funnel in **Question 2(e)(i)**.

- Candidates should use relative atomic masses given in the Periodic Table. There were many instances of the relative atomic masses of K and S (39.1 and 32.1 respectively) being quoted as 39 and 32 in **Question 1(a)**.

General comments

The paper gave students the opportunity to display their knowledge of practical chemistry, and to exercise their ability to plan, analyse and evaluate.

If a single answer is asked for, two (or three) answers should not be given as incorrect statements may contradict correct answers.

Candidates should know that at A level, numerical answers should reflect the appropriate number of significant figures. Most numerical answers, if not indicated otherwise, should be to three significant figures. One significant figure will almost certainly be insufficient.

Comments on specific questions

Question 1

(a) Most candidates gave the correct answer, 0.486 g, to 3 significant figures. With correct working, 0.49 g was allowed, but several candidates rounded to 0.5 g and were not given credit.

Many candidates used A_r values which were not those given in the Periodic Table on Page 16. Most frequently used incorrect A_r values were S: 32 (instead of 32.1) and K: 39 instead of 39.1.

(b) Many excellent answers were seen.

Weaker candidates unnecessarily transferred the solid potassium thiocyanate from the 50 cm^3 beaker to a larger beaker prior to dissolving in step 1.

One common error was omission of rinsing the 50 cm^3 beaker after transfer of aqueous potassium thiocyanate formed in step 1 to the volumetric flask. The most common error was the omission of inversion of the volumetric flask to ensure a truly homogeneous solution.

Other errors included:
- assuming the solid potassium thiocyanate was aqueous

- adding more than 50 cm^3 of distilled water to dissolve the potassium thiocyanate in the 50 cm^3 beaker
- transferring solid potassium thiocyanate directly into the volumetric flask
- transferring the aqueous potassium thiocyanate formed in step 1 into the volumetric flask using a pipette or burette
- using a conical flask (or a beaker) instead of a volumetric flask
- filling the volumetric flask rather than just adding distilled water to the graduation mark.

(c) (i) The most frequently seen incorrect response was to avoid gaseous products from escaping, even though none were produced. Many candidates believed that a gas would be produced, despite being given the equation for the reaction, with state symbols, in the stem of the question. Using a bung to seal the flask to prevent its escape would be dangerous.

A minority of candidates correctly stated that sealing the flask with a bung was to limit the amount of air/oxygen that could enter the reaction mixture. Only the most able candidates were able to describe the chemical effect of atmospheric oxygen i.e. oxidation of Fe^{2+} ions.

(ii) The most common answer was 'to allow the reaction to reach completion'. This demonstrated a lack of appreciation that an equilibrium was required, and time was needed to achieve this.

(iii) Most candidates did not make use of the equation given and although stronger candidates recognized the precipitate as elemental silver, many others opted for salts such as silver sulfate or iron salts. Weaker candidates opted to give a variety of colours of the precipitate.

(d) (i) Candidates had to state that concordant titres had been achieved and to give the correct explanation that the titres were concordant because two titres were within 0.10 cm^3 of each other to be awarded credit.

It was evident that there was confusion about concordant tires. Errors included:
- assuming (two) titres had to be equal
- assuming (two) titres could be 'similar'
- assuming (two) titres had to be within 0.2 cm^3 or 0.05 cm^3 or even 0.01 cm^3
- assuming (two) titres had to be within a certain percentage (usually 10%) of each other.

(ii) Candidates continue to improve in determining percentage errors. Many still omit to show how the numerator of 0.1 is calculated from an error of ± 0.05 cm^3.

The most common error was to assume that the error in a single reading (i.e. ± 0.05 cm^3) divided by the titre gave the percentage error.

Another common error was to assume that each burette reading had an error of ± 0.5 cm^3 or ± 0.005 cm^3.

(iii) Most candidates were able to make the connection that a smaller percentage error would be achieved with a larger titre.

One common error was to state there would be a 'lower uncertainty'. This is incorrect as the uncertainty in both sets of burette readings is identical.

Other errors included references to a visible advantage in judging an endpoint or that a larger titre meant a longer time taken and therefore more accuracy.

(e)(i)/ (ii)/(iii) Many blank answer spaces were seen for this set of calculations.

Working out for parts **(i)** and **(ii)** was often very untidy and involved multiple different attempts using different methods. It was often difficult to identify the final answer due to multiple crossings out. Candidates are reminded not to round values until the end of a calculation as rounding values obtained during intermediate steps can cause accumulated errors.

The least achieved answer was part **(ii)** where candidates had to appreciate it was the equilibria balance which needed to be used to calculate the concentration of Fe^{3+}(aq) ions not simply the same molar concentration as Ag^+(aq) in part **(i)**.

Part **(iii)** often yielded full credit as candidates were able to insert their values for parts **(i)** and **(ii)** into the formula given for determining K_c.

Weaker candidates often did not score the mark for calculating a value for K_c but were able to determine the correct units, $dm^3\ mol^{-1}$. IGCSE units of dm^3 / mol were not credited.

(f) (i) Many candidates recognised that the relationship proposed was false, describing it correctly in terms of the relationship between increasing temperature and decreasing K_c.

Others correctly stated the relationship proposed was false because the line was not straight (curved) or had a negative gradient.

(ii) This was well answered with a very large majority of candidates referring to the lack of an anomalous point.

(iii) The question asked candidates to 'use the data displayed in Fig. 1.1'. Many did not do this and gave answers based upon bond formation.

Most of the candidates understood that the forward reaction was exothermic based upon the graph showing that there were lower values of K_c at higher temperatures.

Question 2

(a) (i) Most candidates realised that 25.00 cm^3 has a precision which requires volumetric apparatus, ideally a pipette, for the transfer of lake water. The use of a measuring cylinder is inappropriate here.

(ii) Candidates are becoming more aware of the syllabus requirement of wearing chemically resistant gloves for handling irritant materials. 'Gloves' alone is insufficient. The key point is that the gloves must be chemically resistant.

(b) (i) Most candidates completed the table correctly.

(ii) Most candidates were able to identify the volume of $Ba(OH)_2(aq)$ added as the independent variable.

(c) Most candidates were able to plot the 9 points correctly as every plot was on a major vertical grid line. The most common incorrect plots were (35.00, 50 400), often plotted at (35.00, 54 000), and (40.00, 63 700) often plotted at (40.00, 62 700).

Many candidates plotted all *y* co-ordinates to the nearest 1000 possibly as this made the *y* co-ordinate easier to plot as it would be on an existing grid line.

Achieving two acceptable lines of best fit was a little more challenging as the points did not all fit on the lines. A 'first to last point' straight line between point 5 and point 9 on the right-hand line was not accepted.

(d) (i) While most candidates achieved a good intersection on the grids, there was a considerable number of mistakes in reading the volume from the scale, for example, reading 17 cm^3 as 15.4 cm^3.

Candidates whose intersect was not on the grid could not be credited with this mark.

(ii) Most candidates were able to correctly calculate the concentration of $SO_4^{2-}(aq)$ from their volume of $Ba(OH)_2(aq)$ in **(d)(i)**.

(e) (i) Few candidates successfully drew the required labelled diagram. Many candidates had little idea of how to carry out simple filtration.

Often, the relationship between funnel and filter paper was unclear or labels were missing.

Filter papers were often used without filter funnels. Some filter papers were being used as horizontal unfolded sheets. Diagrams, particularly 3-D diagrams, often did not show a filter paper inside the funnel.

(ii) Most candidates gained credit for rinsing the residue, but many incorrect responses were seen. Examples included:

- re-filter the filtrate
- leave more time for filtration to complete
- drying the residue with filter paper
- weighing the residue before drying.

(iii) Most candidates were familiar with the idea of achieving constant mass to confirm the residue was completely dry, but some omitted the necessary heating aspect

Common errors included:

- drying the residue with filter paper
- leaving to cool before finding the mass.
- using anhydrous copper(II) sulfate / anhydrous cobalt(II) chloride

(iv) This was answered well with most candidates understanding that the concentration of mass of $SO_4^{2-}(aq)$ would be higher because of the remaining water, leading to the perceived mass of residue and, consequently the number of moles of $BaSO_4$, being higher.

Weaker candidates thought that the remaining water would dilute the solution and the concentration would decrease.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- Extensive A Level practical work is an essential precursor to success in this paper; theory alone is not enough.

Candidates are encouraged to

- read questions carefully and respond precisely to the command word and given information.
- show a good understanding of experiments by stating clearly why steps, reagents, and methods are chosen in their responses.
- develop strong evaluation skills by identifying specific weaknesses in the methods used, explaining their effects on the results and suggesting realistic, targeted improvements.

General comments

Overall, candidates performed well. The paper was accessible to most candidates. There were very few 'nil response' questions, and almost all candidates produced fully legible responses.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to complete this calculation successfully. There were very few incorrect responses.

(ii) The preparation of a standard solution is a routine laboratory procedure, and most candidates showed a good knowledge of the method. The need to use distilled water was almost universally identified. Common errors included failing to wash the beaker during transfer to the volumetric flask or not describing an appropriate method for mixing the final solution.

(b) (i) Most candidates correctly identified a 20.0 cm^3 volumetric pipette as the most suitable apparatus for transferring the solution. Candidates should specify the type of pipette, as the term 'pipette' alone is ambiguous and does not demonstrate sufficient precision. Many candidates incorrectly suggested the use of a burette, revealing confusion between apparatus used for titration and for the accurate transfer of a fixed volume. A small minority of candidates selected a measuring cylinder, not appreciating the level of accuracy required.

(ii) Many candidates found this question challenging. The key to answering correctly was to identify which of the substances involved in the titration would react with the barium ions. A common error was the assumption that barium ions would react with silver ions or nitrate ions. Another frequent misconception was that the chromate ions oxidised the barium ions, rather than the two ions reacting together to form an insoluble salt. Candidates should be reminded that barium, as a Group 2 metal, forms only Ba^{2+} ions, which cannot be oxidised.

(iii) Most candidates correctly identified that wearing chemically resistant gloves would be the most appropriate precaution when handling irritant materials, such as alkaline aqueous iodine.

(c) (i) Many candidates demonstrated familiarity with the requirement for concordant results, correctly identifying these as two titres within 0.10 cm^3 of each other. The most common incorrect response

was to state that the titres used were simply the closest values, without reference to the required tolerance.

(ii) Many candidates correctly recognised that the maximum uncertainty in a quantitative measurement is half the difference between the closest calibrations, giving an uncertainty of ±0.05 cm³. They also identified that two burette readings were required (0.30 cm³ and 20.90 cm³) and correctly calculated the maximum percentage error in the volume of 20.60 cm³ as (2 × 0.05)/ 20.690 × 100 = 0.485%. Clear and well-structured working leading to the correct answer was present in many responses. A small number of candidates applied the correct calculation method but incorrectly assumed the uncertainty in each burette reading to be ±0.005 cm³.

(d) (i) This calculation was correctly carried out by most candidates.

(ii) This question was generally answered well. Some candidates correctly used the 1 : 2 mole ratio of $BaCl_2$:$AgNO_3$ and divided their answer to part **(d)(i)** by 2, obtaining 5.15×10^{-4} mol as the amount of $BaCl_2$ in 20 cm³, but did not scale this value by a factor of 250/20.

A less common error was to calculate 0.0500 × 250/1000 and then divide by 2, leading to an incorrect value of 6.25×10^{-3} mol.

(iii) Most candidates who completed **(d)(ii)** were able to gain full credit for this part. Many candidates who got **(d)(ii)** incorrect also gained full credit from error carried forward, most commonly getting an M_r of 158, resulting from the correct processing 5.15×10^{-4} from 1**(d)(ii).**

(e) Most candidates selected a method based on the thermal decomposition of $BaCl_2 \cdot xH_2O$ and were able to describe the key steps required to carry out the practical successfully. A small number did not specify an appropriate container for heating the solid, with some suggesting the use of an evaporating dish or, in more extreme cases, spreading the solid directly onto a gauze for heating.

Question 2

(a) Many candidates recognised that adding the gas to the syringe was carried out to prepare the apparatus before making the measurement. The strongest responses explained that introducing 50 cm³ of the gas being tested was used to flush the syringe, thereby removing any air or other gas already present and ensuring that the apparatus initially contained only the gas being tested.

(b) (i) Most candidates completed the results table as directed. Few were unable to correctly round to three significant figures or give values to two decimal places.

(ii) Recognition of the dependent variable as the time taken was achieved by most candidates. No credit was given for identifying rate of effusion as the independent variable, as this is a derived value used for graphing or analysis, not the variable that was directly measured experimentally.

Candidates who are used to finding the dependent variable by reading the y-axis, gave the answer as rate of effusion rather than time.

(iii) Few candidates identified the size of the hole in the aluminium foil as a variable that needed to be controlled. The most common credited responses instead referred to atmospheric pressure or the volume of the gas being tested.

The response ‘volume of gas’ alone was considered ambiguous and was not awarded credit.

(c) Most candidates plotted data points on the grid with appropriate accuracy and drew a suitable line of best fit. In this question, the line of best fit should be a straight line that passes very close to all but the anomalous point.
A significant number of candidates did not gain the plotting mark due to placing points directly on gridlines when this was inappropriate. Data points should be plotted correctly when they do not correspond exactly to a grid line intersection. When points were incorrectly plotted many were able to gain credit for drawing the line of best fit.

(d) Few candidates did not pick out the most anomalous point. Many were also able to state that timing was an issue and clearly identified one of the correct reasons for the anomaly in this case.

(e) The graph provided clear evidence to support the conclusion that the rate of effusion of a gas is proportional to $\sqrt{(1/M)}$; a straight line that passes through the origin (0,0). A large number of candidates did not refer to one of these required features in their answer and were not awarded credit.

(g) (i) Where candidates correctly determined the rate of effusion as 1.58 and recognised that this corresponded to a value of approximately 0.24 for $\sqrt{(1/M)}$, the correct molar mass was usually obtained. Some candidates misread $\sqrt{(1/M)}$, from their graph, often as 0.28 or 0.29 and hence a molar mass of approximately 11.9 was obtained. As a result, these candidates only gained partial credit.

(ii) Using the data provided, the correctly calculated value of *M* for the gas mixture lay in the range 16.7 to 17.4, that is, greater than the relative molecular mass of methane. This implies that the other gases in the mixture must have had an average relative molecular mass greater than 17.4. Many candidates found this part of the question challenging. Common incorrect responses suggested that the other gases had a relative molecular mass of 17.4 minus 16 and proposed hydrogen as a possible identity.

(h) Many candidates did not explain that the rate of effusion increased because the molecules themselves gained kinetic energy. Instead of specifying that it was the molecules that gained energy, several candidates vaguely stated that the gas gained energy, which lacked clarity and did not earn credit.

CHEMISTRY

Paper 9701/54
Planning, Analysis and Evaluation

Key messages

- A significant amount of information about unfamiliar experiments is often given in the questions. This information needs to be read carefully to answer the questions appropriately.
- When answering 'Suggest' questions, candidates should be discouraged from giving more than one answer because incorrect statements may contradict a correct answer.

General comments

Most candidates attempted all the questions showing that there was sufficient time to complete the paper. Both questions were answered equally well. The calculation, data handling and gradient questions were mostly answered to a high standard.

Some questions require a written explanation or suggestion. When writing the answer, it is better to avoid using 'it'. This avoids giving an ambiguous answer. An example from **Question 1(b)** is to write '$MnSO_4 \bullet H_2O(s)$ is dissolved' and not 'it is dissolved'.

Units should always be included in written answers if relevant. An example from **Question 1(e)(ii)** is to write 'titrations 2 and 3 are within 0.1 cm^3' and not 'titrations 2 and 3 are within 0.1'.

Comments on specific questions

Question 1

(a) Most candidates gained credit. Some did the correct calculation and did not gain credit because the answer was to the incorrect number of decimal places (two was asked for). A few miscalculated the molar mass of $MnSO_4 \bullet H_2O$ with missing out the H_2O being the most common error.

(b) Questions about making a standard solution are regularly seen in paper 5 and this question was well-answered with most candidates gaining partial credit. Candidates are reminded that the essential piece of volumetric apparatus to make a 100 cm^3 volume of solution is a '100 cm^3 volumetric flask' and that once the volumetric flask has been topped up to the 100 cm^3 mark with distilled water, the flask needs to be inverted several times.

(c) (i) Many candidates gained credit. An answer of chemically resistant gloves was expected, and gloves alone was not credited.

(ii) There was a tendency to give more than one answer to this question. The most common error was relating cooling to a need to reduce the temperature which does not give any additional information.

(d) (i) This question was answered correctly by many candidates. Vague answers included more than one suggestion and often about non-specific effects on the reaction. It was not enough to say that the final result would be less accurate because that could apply to almost any change made.

(ii) An answer of volumetric pipette was expected here which most candidates answered correctly.

(iii) Most candidates understood the use of starch solution. Some answers did not go far enough stating that starch solution was present to detect the end point, without giving the idea that starch solution makes the end point clearer.

(e) (i) Almost all candidates answered this question correctly.

(ii) This question was not as well-answered as **(e)(i)**. Some candidates gave very good answers, specifically referring to titrations 2 and 3 being within 0.1 cm^3 of each other (or concordant). More detail than stating titres were close enough was required.

(iii) A question like this is often asked on paper 5 and candidates are answering them well, showing the working as required. It is essential to read the question carefully as some candidates used the mean titre instead of the titration 3 titre value.

(f) (i)(ii)(iii) Many candidates on this paper demonstrated an ability to answer calculation questions such as these very well. **Part (iii)** was the most difficult calculation on the paper and answered correctly by nearly half the candidates. The most common incorrect final answer to **(iii)** was half the correct answer with candidates using the 500 cm^3 volume of solution **Z** instead of the initial sample size of 250 cm^3 in their calculation. Candidates should be advised to write their workings out stepwise to help avoid making mistakes.

Question 2

(a)(i) The idea of drying the block earned many candidates credit. Ideas which did not gain credit included the reaction of water with tin and the dilution of the iodine solution.'

(ii) The wording in the question was to encourage candidates to focus on the solubility of iodine in water. Not all candidates answered in this way and if a correct comparison of the solubility of iodine in water and methylbenzene was given, credit was awarded.

(iii) This question was less well answered. A specific answer based on the experiment was preferred rather than a general one about the use of a balance. Simply stating more accurate was not enough for credit to be awarded.

(iv) This question was answered well by many candidates. Errors such as leaving out the tin block or changing the solvent or temperature suggested that the question had not been read with enough care.

(b) Most candidates answered this question correctly. Candidates should be reminded that when an answer to a given number of decimal places (3 decimal places here) is requested, if there is a final zero, the zero must be given to show the precision of the value. Here, 0.12 was not acceptable for 0.120 in the third row of the table.

(c) (i) Points were correctly plotted. Some candidates omitted the point at the origin which was part of the given data in the table. Most candidates plotted the points exactly on the correct line for the *x*-coordinate values, but a few made mistakes when plotting the *y*-coordinate values on the scale given. Candidates are advised that is not good practice to round the values to plot on the nearest line.

The line of best fit was close to all points except the anomalous point and did not cause any difficulties.

(ii) Most candidates circled the anomalous point correctly. Candidates are encouraged to use values from the graph to clarify their reason and make sure the reason relates directly to how the experiment is carried out. In this case, stating that the mass reading (for this point) was taken before 200 s was the best answer to give.

(d) Candidates were very good at finding the gradient of their graph. Candidates are reminded to pick two points from their line of best fit that are far enough apart to make use of more than half the graph. Candidates are expected to be able to read points from the graph to the nearest half square

so that was to the nearest 0.0025 g; using values from the table (given to the nearest 0.001 g) only made sense if the point was exactly on the line.

(e) (i) This question was very well answered.

(ii) The independent variable is the concentration of iodine solutions which are made up in the experiment because the rate of reaction is then determined by the measurements for each concentration.

(iii) Candidates were asked to use values from a table. Including some of the values given in column 3 and/or column 4 of the table was the best way of addressing this. Stating that if concentration halved, then the rate also halved was not sufficient to gain the second mark. This question was well answered with many candidates gaining full credit.