CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Five questions were found to be particularly difficult. **Questions 17**, **21**, **24**, **34** and **40**. These questions will be looked at in greater detail.

Comments on specific questions

Question 17

The most commonly chosen incorrect answer was **C**. 43 per cent of candidates chose this answer. This shows the majority of candidates recognised XO_4^{2-} as SO_4^{2-} but had more difficulty with element Y.

Question 21

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

- Reaction 1 produces hydrogen chloride gas, so the fumes described in the question consist of hydrogen chloride gas. This gas cannot oxidise potassium iodide to iodine so the answer must be **C** or **D**.
- Reaction 2 occurs in the presence of aqueous ammonia. Silver chloride is soluble in aqueous ammonia, so no precipitate is seen. Therefore, the answer is **C**.

Question 24

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

- Statement 1 is not true – ammonia molecules can form coordinate bonds with hydrogen ions, but not with hydroxide ions.
- Statement 2 is true – an NH_4^+ ion is able to donate an H^+ ion, forming an ammonia molecule.
- Statement 3 is true – the bond angle in an NH_4^+ ion is 109.5°, the bond angle in an NH_3 molecule is 107°.

Question 34

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

In order to produce a dicarboxylic acid, a diol must be able to lose both of its terminal carbon atoms as part of a molecule of iodoform, CHI_3. This means both ends of the molecule must be $–CH(OH)CH_3$. The only molecule that matches this description is pentan-2,4-diol.

Question 40

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

The majority of candidates were able to deduce that statements 1 and 3 are correct but were unsure of statement 2. Peak Z has an m / e value of 74 so it is produced by $^{37}Cl_2$ molecules. 37.0 g of these molecules is exactly half a mole of molecules, which is 3.011×10^{23} molecules, so statement 2 is also correct.

CHEMISTRY

Paper 9701/12
Multiple Choice

Question Number	Key
1	D
2	C
3	D
4	C
5	D
6	B
7	C
8	C
9	B
10	D

Question Number	Key
11	C
12	C
13	A
14	D
15	D
16	D
17	A
18	C
19	A
20	B

Question Number	Key
21	C
22	A
23	A
24	C
25	B
26	D
27	A
28	B
29	A
30	C

Question Number	Key
31	A
32	B
33	C
34	B
35	B
36	D
37	A
38	D
39	B
40	A

General comments

Five questions were found to be more difficult, **Questions 13**, **26**, **31**, **33** and **37**. These questions will be looked at in greater detail.

Comments on specific questions

Question 13

The most commonly chosen incorrect answer was **C**. It was necessary to apply Le Chatelier's principle to this question. Any alkaline substance will increase the concentration of OH^-, causing the position of the equilibrium to move to the left. Ammonia is alkaline, therefore adding ammonia will increase the concentration of OH^- thus increasing the amount of $Ca_5(PO_4)_3OH$ that is present.

Question 26

The most commonly chosen incorrect answers were **B** and **C**. Compound X contains a C=C double bond which will produce cis and trans isomers. For each of these two isomers the secondary alcohol group will produce two optical isomers, making four isomers. For each of these four isomers the methyl side group will produce two optical isomers, giving a total of eight stereoisomers.

Question 31

The most commonly chosen incorrect answer was **C**. This suggests that the majority of candidates knew that the set of reagents in row 1, and the set of reagents in row 3 would both produce 2-chloro-2-methylpropane as one of the organic products. The difficulty of the question therefore depended upon the reagents in row 2.

$SOCl_2$ will cause the replacement of the OH group by a chlorine atom to give 2-chloro-2-methylpropane.

Question 33

The most commonly chosen incorrect answer was **D**. Hot acidified $K_2Cr_2O_7$ will oxidise the $–CH_2OH$ group to a $–CO_2H$ group.

Question 37

The most commonly chosen incorrect answers were **B** and **C**. In the scenarios one mole of propanoic acid produces half a mole of hydrogen, so 3.70 g of propanoic acid, which is 0.050 moles, will produce 0.025 moles of hydrogen. This amount of gas has a volume at s.t.p. of 560 cm^3.

CHEMISTRY

Paper 9701/13
Multiple Choice

Question Number	Key
1	A
2	C
3	C
4	D
5	A
6	D
7	B
8	D
9	B
10	A

Question Number	Key
11	A
12	A
13	C
14	A
15	A
16	B
17	D
18	C
19	C
20	B

Question Number	Key
21	C
22	C
23	C
24	C
25	B
26	D
27	B
28	C
29	D
30	B

Question Number	Key
31	B
32	D
33	D
34	D
35	B
36	A
37	B
38	C
39	A
40	A

General comments

Five questions were found to be particularly difficult. **Questions 17**, **21**, **24**, **34** and **40**. These questions will be looked at in greater detail.

Comments on specific questions

Question 17

The most commonly chosen incorrect answer was **C**. 43 per cent of candidates chose this answer. This shows the majority of candidates recognised XO_4^{2-} as SO_4^{2-} but had more difficulty with element Y.

Question 21

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

- Reaction 1 produces hydrogen chloride gas, so the fumes described in the question consist of hydrogen chloride gas. This gas cannot oxidise potassium iodide to iodine so the answer must be **C** or **D**.
- Reaction 2 occurs in the presence of aqueous ammonia. Silver chloride is soluble in aqueous ammonia, so no precipitate is seen. Therefore, the answer is **C**.

Question 24

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

- Statement 1 is not true – ammonia molecules can form coordinate bonds with hydrogen ions, but not with hydroxide ions.
- Statement 2 is true – an NH_4^+ ion is able to donate an H^+ ion, forming an ammonia molecule.
- Statement 3 is true – the bond angle in an NH_4^+ ion is 109.5°, the bond angle in an NH_3 molecule is 107°.

Question 34

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

In order to produce a dicarboxylic acid, a diol must be able to lose both of its terminal carbon atoms as part of a molecule of iodoform, CHI_3. This means both ends of the molecule must be $–CH(OH)CH_3$. The only molecule that matches this description is pentan-2,4-diol.

Question 40

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

The majority of candidates were able to deduce that statements 1 and 3 are correct but were unsure of statement 2. Peak Z has an m / e value of 74 so it is produced by $^{37}Cl_2$ molecules. 37.0 g of these molecules is exactly half a mole of molecules, which is 3.011×10^{23} molecules, so statement 2 is also correct.

CHEMISTRY

Paper 9701/21
AS Level Structured Questions 21

Key messages

Candidates were not familiar with some of the fundamental definitions required at AS level.

General comments

A common misconception stated by candidates was that covalent bonds, and not intermolecular forces, are broken when species melt or boil.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to give a correct electronic configuration of: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. A few candidates included the $3d^7 4s^2$ given in the question. This was not required in the answer.

(ii) This question was well answered with most drawings attempting to represent a sphere as a circle. A few diagrams showed the x, y and z axes drawn to represent a 3D shape.

(iii) Several candidates gave an answer of one, whilst many gave the correct answer.

(b) Most candidate answers were correct for the total number of protons and neutrons, but the total number of electron shells, for rhodium, were often incorrectly given as 4.

(c) (i) The definition was not well answered. Many candidates stated that it was the average mass of an isotope/weighted average mass of an isotope or the average mass of isotopes. Very few answers gave a complete definition.

(ii) Many candidates incorrectly used all three isotopes to calculate the A_r of iridium and divided by 100 or used the two isotopes of iridium but divided by 100 instead of by 50.

(d) (i) Many candidates were aware that to calculate an integer value of x, the water of crystallisation in $RhCl_3 \bullet xH_2O$, a mole ratio calculation was required. The ratio of H_2O to $RhCl_3$ was given/deduced as 20.5 per cent : 79.5 per cent by mass, from which a mole ratio of 0.38 :1.14 can be calculated. Many candidates chose a slightly different route and used the expression $18x \div (209.4 + 18x) = 0.205$, to correctly calculate a vale of $x = 3$.

(ii) Many candidate answers mentioned that stereoisomers contained the same 'molecular formula' but omitted the fact that they also contained the same 'structural formula', which is the key feature for this definition. Several candidates correctly stated that the stereoisomers had 'different arrangements in space' but made no mention of what was arranged differently in space e.g. atoms/groups.

(iii) Many candidates failed to recognise that a single product would be formed and gave explanations about adding extra CH_2 units to the chain.

iv) The diagrams of the two stereoisomers of but-2-ene were often correct. Errors included confusion on the position of the C=C, in the chain, on one or both structures and incorrect groups or incorrect arrangements.

Question 2

(a) (i) The colours of the Group 17 elements, chlorine, bromine and iodine were not well known with common errors being 'yellow' for chlorine and 'purple' for iodine. Many candidate answers stated that the colours became darker down the group which was insufficient.

(ii) Most candidate answers correctly stated that the oxidising strength of the elements chlorine, bromine and iodine decreased down the group.

(iii) Candidate answers that were awarded credit stated that 'white fumes' would be observed although strictly this occurs only when moisture is present.

(iv) Many candidate answers linked the decreasing thermal stability of hydrogen halides to weaker intermolecular forces of attraction. Some candidates only mentioned bond length and did not link the decrease in thermal stability to the decrease in bond strength of the H-Hal bond.

(b) (i) Many candidate answers stated that it was an 'unpaired electron or a lone pair of electrons'. The requirement for a species to be specified, that contained 'one or more unpaired electrons', was often omitted.

(ii) This question was well answered.

(iii) Few candidates were awarded full credit here. Incorrect responses showed that candidates were not clear what a propagation step involved and gave initiation or termination steps instead. Some included ions instead of radicals or gave H radical as an incorrect response.

(c) (i) Many candidates recognised that NaOH was required to convert chlorine to $NaClO$, but the requirement for the NaOH to be in aqueous solution and the conditions to be 'cold' were regularly omitted.

(ii) The definition of disproportionation was well answered by many candidates.

(iii) This equation was well known.

(iv) This question was well answered by many candidates. Several candidates lost marks for giving additional incorrect observations for example: a brown gas of NO_2 is also formed. Those candidates who described how the Cl^- ion was formed, prior to its reaction with Ag^+ (in $AgNO_3$) lost credit by failing to appreciate that the $CHCl_3$ was initially hydrolysed to form Cl^-. Many stated that the Cl^- was contained in $CHCl_3$, and not a product from its hydrolysis.

Question 3

(a) (i) This question was well answered with many candidates stating that graphite was a conductor of electricity with covalent bonding and that tin was a giant structure.

(ii) Many candidate answers described the layers/hexagon rings with IMFs between layers, a feature of graphite that was not required in this question.

(iii) Many candidates' answers did not gain any credit for either not mentioning that the electrons were 'delocalised' or that they were 'moving', which are the necessary criteria for tin to conduct electricity.

(b) (i) The most common errors were to give the formula for magnesium chloride as $MgCl$ and to use 1 mole of hydrochloric acid, in the equation, instead of 2 moles.

(ii) Increases was correctly stated by many candidates.

(iii) Many candidates gained some credit for appreciating that the ammonium carbonate donated a proton and the NaOH accepted this proton. Few answers gained full credit for stating that the ammonium ion, NH_4^+, is the actual species that behaves as an acid, by donating the proton, and it is the OH– ion that is accepting these protons.

(c) (i) Correct completion of the graph was shown by many candidates.

(ii) Incorrect answers often omitted state symbols or gave unbalanced equation with $2e^-$ on the right hand side of the equation.

(d) (i) There were many correct candidate answers stating an increase in the number of electrons, from CH_4 to PbH_4, often followed by incorrect comments that there was an increased nuclear attraction between the nucleus and outer electrons, or that the nuclear charge outweighed the shielding effect. After discussing the impact of the increased intermolecular forces of attraction, IMFs, down the group, many candidates went on to discuss the breaking of bonds.

(ii) The shape of a molecule of SiH_4 was well answered.

(e) (i) Many correct answers for the equation were present. A common error was to use HCl as a reactant, instead of Cl_2.

(ii) Most candidates gave the correct observations of steamy/misty/white fumes or a white precipitate when $SiCl_4$ is added to water.

(iii) Credit was given to candidates for recognising that the structure and bonding of solid, SiO_2, was giant covalent and liquid $SiCl_4$ as simple molecular/simple covalent. There were few correct explanations relating to the difference in melting points of these two compounds. Many candidates referred to the need for more energy to break the strong covalent bonds in SiO_2 but failed to mention anything regarding the energy requirements for breaking the intermolecular forces of attraction, IMFs, between liquid $SiCl_4$ molecules. Several answers compared the strength of the covalent bonds in both SiO_2 and $SiCl_4$ and many answers incorrectly stated that the structure of SiO_2 contained double bonds between the Si and O atoms.

(f) Many candidates gave the correct answer.

Question 4

(a) (i) The mechanism attracted many good answers. The common errors included: arrows from the negative charge (on the CN^- ion) instead of from the lone pair on the C atom, missing polarity, specifically missing the δ+ on the H (of H-CN), and incorrect attack of the intermediate by the CN^- ion.

(ii) Many answers stated that there were two CH_3 groups on one C atom in A but did not go further to explain the significance of this in terms of the lack of optical isomerism in A. Credit was given for stating that no chiral centre was present or that the central C atom was not bonded to four different atoms/groups.

(b) Candidates often stated that the mineral acids HCl or H_2SO_4 were required for the hydrolysis reaction of a CN group to a carboxylic acid but missed the requirement for the acid to be dilute or aqueous.

(c) (i) The equation was frequently correct. A common error was the omission of 2(H), from the equation, or using just 2H, without the brackets.

(ii) The name of compound C was well known.

(d) Most candidate answers stated that an orange precipitate was formed when propanone was reacted with 2,4-DNPH.

(e) A common answer was that 'Fehling's reagent only reacts with aldehydes', with no reference to any chemistry in this reaction. Fehling's reagent behaves as an oxidising reagent and ketones are not easily oxidised, hence, there is no reaction between Fehling's reagent and propanone.

(f) (i) Many candidate answers stated that the absorptions at 2850 – 2950 cm^{-1} were attributable to a C-H bond. As all three compounds in the question contained groups containing C-H bonds these compounds were indistinguishable using these absorptions.

(ii) Many candidates correctly identified the absorption at 2200 – 2250 cm^{-1}, which was unique to compound A, as it was the only compound containing a C≡N bond. As all three compounds, A, B and C contained an O-H bond, no credit was given for frequent mention of this absorption.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions 22

Key messages

Candidates who gave answers with accurate and relevant details which specifically addressed the question asked scored more marks.
Candidates who were able to use key terms, specific to the syllabus and in the correct context were most successful.
Candidates who produced imprecise and ambiguous answers, which did not address the question asked scored lower marks.

General comments

Candidates are expected to balance all chemical equations. This includes ionic equations.
Equations that represent a specific ionisation energy should always refer to the symbol of the element given in the question and should include state symbols.

Comments on specific questions

Question 1

(a) (i) Understanding of 'ground state' was rarely described correctly. Confusion of 'ground state' with 'natural' or 'standard' state was seen.

(ii) Many candidates gave the correct representation of the arrangement of electrons in the 3d and 4s orbitals.

(iii) The most common incorrect answer was '6'; perhaps deduced by those who considered only one of the energy levels n = 2 or n = 3.

(b) (i) Most candidates gave the correct deduction of the number of protons and neutrons in each species.

(ii) Confusion of the terms 'relative atomic mass' with 'relative isotopic mass' was seen in weaker candidate responses. Comparisons of mass were often incomplete or incorrect, examples included no identification of the specific carbon isotope.

(iii) Fully correct answers used the relative isotopic mass given in Table 1.1 correctly and gave their final answer to 2 decimal places. Weaker responses did not select the relevant data from Table 1.1. Final answers were not always given to the 2 decimal places specified.

Question 2

(a) (i) The formula of sodium oxide was not well known. In equations where correct formulae were shown, a significant proportion were not balanced.

(ii) Candidate answers were rarely given in terms of an aluminium cation and an oxide anion. When ions were described, they were generally shown with the appropriate number of outer electrons; charges on the ions were sometimes omitted or incorrect.

(iii) Weak candidate answers did not fully address the question and explained why the maximum oxidation state varies because of the variable number of valence electrons.

(b) (i) Many candidate answers referred to $Mg(OH)_2$ with a pH of a slightly acidic solution rather than weakly alkaline. The product of the reaction of P_4O_{10} and H_2O was not well known, $P(OH)_5$ was a common incorrect answer.

(ii) This equation proved to be demanding. Common errors included equations which were incorrectly balanced or showed ammonia as a product of the reaction.

(iii) This question was answered well by candidates. Occasionally the same structure was shown twice, usually with propan-1-ol as both answers.

(iv) Excellent candidate answers were seen and these explained why there were fewer $H^+(aq)$ in solution in terms of the increase in strength of O-H bond due to the positive inductive effect of the ethyl group. Inappropriate use of the term 'electronegativity' instead of 'electron density' was seen. Common misconceptions included the production of OH^- ions when alcohols dissociate or that water fully dissociates or that alcohols contain OH^- ions.

(c) (i) Many candidate answers referred to H_2O although this was not relevant in **(c)(i)**. Weaker responses appreciated that there was an increase in strength of intermolecular forces but did not explain how this change arose. Many candidates gave answers in terms of an increase in size of the molecules or in terms of nuclear attraction, nuclear charge and shielding, which is incorrect. A common misconception described the increase in boiling point due to an increase in strength of permanent dipoles as the group is descended.

(ii) Identification of hydrogen bonds in H_2O was relatively common. The relevant strength of hydrogen bonds in water compared to those intermolecular forces present in the other hydrides was not always included. Incorrect reference to H_2S containing hydrogen bonds was seen and there was ambiguity in answers that referred to the relative strength of the O-H bonds rather than intermolecular hydrogen bonds.

Question 3

(a) (i) Many candidate answers referred to lightning as responsible for one natural occurrence of NO_2. A common incorrect answer was acid rain. Fewer candidate answers described the main source of man-made nitrogen oxides as the internal combustion engine. Lots of candidates incorrectly identified the source as catalytic converters or 'car exhaust' as the origin of nitrogen oxides.

(ii) Very few candidates gave appropriate species in the equation and if they did these equations were not always balanced correctly. Many missed the significance of the word 'direct' in the question and attempted to give an equation showing the role of NO_2 as a catalyst in the production of sulfur-based acid rain.

(iii) Candidates who were familiar with this area of the syllabus described how PAN forms from NO_2. Common incorrect descriptions included acid rain, water, oxygen, carbon monoxide, carbon dioxide or ozone reacting with NO_2.

(iv) Correctly balanced equations were common. Typical errors included incorrect formula of nitric acid or calcium nitrate or production of H_2 rather than H_2O.

(v) Some candidate answers described the production of a brown gas. Others focused on the production of a white solid even though the original compound is also a white solid.

(b) (i) Occasionally incorrect oxidation states were seen; –1 and +3 were common incorrect answers.

(ii) The majority of candidates identified aluminium as the correct species that is oxidised. The weakest answers described one of the two products of the reaction.

(iii) Excellent answers gave a full description of the formation of a dative bond due to the lone pair on the nitrogen atom accepting a proton. Weaker candidate descriptions only referred to the ability of ammonia to form a dative bond.

(iv) Identification of an appropriate shape for $Al(OH)_4^-$ was present in a significant proportion of answers.

(c) (i) Inclusion of state symbols for ionisation energy equations are essential. Some equations showed addition of an electron, other equations were incorrectly balanced.

(ii) A general increase in ionisation energy was shown by most candidates. Many answers showed a larger increase in energy for one of the ionisation processes, with the exact ionisation process often incorrectly identified. Weaker answers confused the trend in ionisation energy across a period with the trend of successive ionisation energies.

(d) Phosphorus was sometimes identified incorrectly with ionic bonding or as an ionic structure.

(e) Use of the term ‘simple’ to identify the structure of solids made up of discrete molecules was not well known and the structure of solid nitrogen was often referred to as ‘giant’.

(f) (i) This question highlighted many misconceptions about hybridisation, sigma and pi bonds. These include

- a triple bond involves formation of two sigma bonds and one pi bond
- triple bonds are made when sigma and pi overlap
- hybridisation in P_2 identified as sp^2 or sp^3
- in P_2 overlap of s orbitals creates a sigma bond
- formation of sigma bonds by side-on overlap of orbitals and pi bonds by head-on overlap of orbitals.

(ii) Many candidate responses referred to the appropriate difference in bond strength. Some answers were incomplete, with no comparison of reactivity given. Some candidates misinterpreted the question and explained why they had different bond energy values.

Question 4

(a) Well-rehearsed candidate answers included the accurate placement of curly arrows, dipoles and the correct intermediate. Weaker answers often had ambiguous placement of curly arrows, inappropriate use of partial charges, incorrect dipole on Br_2 and incorrect intermediates.

(b) Correct calculations, sometimes with an appropriate Hess’ cycle in their working, were seen. Incorrect answers were calculated by those candidates that did not fully understand or use the definition of enthalpy change of formation when applying Hess’s law.

(c) (i) The product **A** was correctly shown in many answers. Candidates need to show correct connectivity of the O-H group to the carbon backbone when structures are drawn.
The naming of **B** presented problems for some candidates. Incorrect names often described the incorrect position of Br on the carbon backbone or gave a name which described the wrong number of carbon atoms in the backbone.

(ii) Unambiguous structures were seen in a significant number of candidate answers.

(iii) This question proved to be extremely demanding. All the information provided in the details of Fig. 5.1 needed to be considered, including the three products as well as the reaction conditions.

(d) (i) Correct identification of the type of isomerism was given in a significant number of candidate answers. Chain isomerism was a common incorrect answer even though the two molecules were made up of only two carbon atoms.

(ii) Many candidate answers stated that **F** was a carbonyl compound; this term describes the functional group present in the molecule and is common to both homologous series; aldehyde and ketone.

(iii) Many candidate answers gave appropriate observations for the behaviour of **F** with 2,4-DNPH reagent and Tollen’s reagent. A much smaller number of answers identified a positive reaction with appropriate observation for the reaction with alkaline I_2(aq).

(e) (i) This question proved to be demanding. The strongest candidates gave full explanations of their interpretation of the infrared spectrum by relating relevant wavenumber values at absorption troughs to appropriate bond types and used the molecular ion peak to deduce the molecular mass of **H**. Weaker responses quoted key wavenumber values at troughs in the infrared spectrum and restated that the molecular ion peak in the mass spectrum was at m/e = 60 without explaining what this information actually provides about structure **H**.

(ii) The correct role of reagent **G** was given in many candidate answers. Catalyst was a common incorrect answer.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions 23

Key messages

Candidates were not familiar with some of the fundamental definitions required at AS level.

General comments

A common misconception stated by candidates was that covalent bonds, and not intermolecular forces, are broken when species melt or boil.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to give a correct electronic configuration of: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. A few candidates included the $3d^7 4s^2$ given in the question. This was not required in the answer.

(ii) This question was well answered with most drawings attempting to represent a sphere as a circle. A few diagrams showed the x, y and z axes drawn to represent a 3D shape.

(iii) Several candidates gave an answer of one, whilst many gave the correct answer.

(b) Most candidate answers were correct for the total number of protons and neutrons, but the total number of electron shells, for rhodium, were often incorrectly given as 4.

(c) (i) The definition was not well answered. Many candidates stated that it was the average mass of an isotope/weighted average mass of an isotope or the average mass of isotopes. Very few answers gave a complete definition.

(ii) Many candidates incorrectly used all three isotopes to calculate the A_r of iridium and divided by 100 or used the two isotopes of iridium but divided by 100 instead of by 50.

(d) (i) Many candidates were aware that to calculate an integer value of x, the water of crystallisation in $RhCl_3{\bullet}xH_2O$, a mole ratio calculation was required. The ratio of H_2O to $RhCl_3$ was given/deduced as 20.5 per cent : 79.5 per cent by mass, from which a mole ratio of 0.38 :1.14 can be calculated. Many candidates chose a slightly different route and used the expression $18x \div (209.4 + 18x) = 0.205$, to correctly calculate a vale of $x = 3$.

(ii) Many candidate answers mentioned that stereoisomers contained the same ‘molecular formula’ but omitted the fact that they also contained the same ‘structural formula’, which is the key feature for this definition. Several candidates correctly stated that the stereoisomers had ‘different arrangements in space’ but made no mention of what was arranged differently in space e.g. atoms/groups.

(iii) Many candidates failed to recognise that a single product would be formed and gave explanations about adding extra CH_2 units to the chain.

iv) The diagrams of the two stereoisomers of but-2-ene were often correct. Errors included confusion on the position of the C=C, in the chain, on one or both structures and incorrect groups or incorrect arrangements.

Question 2

(a) (i) The colours of the Group 17 elements, chlorine, bromine and iodine were not well known with common errors being ‘yellow’ for chlorine and ‘purple’ for iodine. Many candidate answers stated that the colours became darker down the group which was insufficient.

(ii) Most candidate answers correctly stated that the oxidising strength of the elements chlorine, bromine and iodine decreased down the group.

(iii) Candidate answers that were awarded credit stated that ‘white fumes’ would be observed although strictly this occurs only when moisture is present.

(iv) Many candidate answers linked the decreasing thermal stability of hydrogen halides to weaker intermolecular forces of attraction. Some candidates only mentioned bond length and did not link the decrease in thermal stability to the decrease in bond strength of the H-Hal bond.

(b) (i) Many candidate answers stated that it was an ‘unpaired electron or a lone pair of electrons’. The requirement for a species to be specified, that contained ‘one or more unpaired electrons’, was often omitted.

(ii) This question was well answered.

(iii) Few candidates were awarded full credit here. Incorrect responses showed that candidates were not clear what a propagation step involved and gave initiation or termination steps instead. Some included ions instead of radicals or gave H radical as an incorrect response.

(c) (i) Many candidates recognised that NaOH was required to convert chlorine to $NaClO$, but the requirement for the NaOH to be in aqueous solution and the conditions to be ‘cold’ were regularly omitted.

(ii) The definition of disproportionation was well answered by many candidates.

(iii) This equation was well known.

(iv) This question was well answered by many candidates. Several candidates lost marks for giving additional incorrect observations for example: a brown gas of NO_2 is also formed. Those candidates who described how the Cl^- ion was formed, prior to its reaction with Ag^+ (in $AgNO_3$) lost credit by failing to appreciate that the $CHCl_3$ was initially hydrolysed to form Cl^-. Many stated that the Cl^- was contained in $CHCl_3$, and not a product from its hydrolysis.

Question 3

(a) (i) This question was well answered with many candidates stating that graphite was a conductor of electricity with covalent bonding and that tin was a giant structure.

(ii) Many candidate answers described the layers/hexagon rings with IMFs between layers, a feature of graphite that was not required in this question.

(iii) Many candidates’ answers did not gain any credit for either not mentioning that the electrons were ‘delocalised’ or that they were ‘moving’, which are the necessary criteria for tin to conduct electricity.

(b) (i) The most common errors were to give the formula for magnesium chloride as $MgCl$ and to use 1 mole of hydrochloric acid, in the equation, instead of 2 moles.

(ii) Increases was correctly stated by many candidates.

(iii) Many candidates gained some credit for appreciating that the ammonium carbonate donated a proton and the NaOH accepted this proton. Few answers gained full credit for stating that the ammonium ion, NH_4^+, is the actual species that behaves as an acid, by donating the proton, and it is the OH– ion that is accepting these protons.

(c) (i) Correct completion of the graph was shown by many candidates.

(ii) Incorrect answers often omitted state symbols or gave unbalanced equation with $2e^-$ on the right hand side of the equation.

(d) (i) There were many correct candidate answers stating an increase in the number of electrons, from CH_4 to PbH_4, often followed by incorrect comments that there was an increased nuclear attraction between the nucleus and outer electrons, or that the nuclear charge outweighed the shielding effect. After discussing the impact of the increased intermolecular forces of attraction, IMFs, down the group, many candidates went on to discuss the breaking of bonds.

(ii) The shape of a molecule of SiH_4 was well answered.

(e) (i) Many correct answers for the equation were present. A common error was to use HCl as a reactant, instead of Cl_2.

(ii) Most candidates gave the correct observations of steamy/misty/white fumes or a white precipitate when $SiCl_4$ is added to water.

(iii) Credit was given to candidates for recognising that the structure and bonding of solid, SiO_2, was giant covalent and liquid $SiCl_4$ as simple molecular/simple covalent. There were few correct explanations relating to the difference in melting points of these two compounds. Many candidates referred to the need for more energy to break the strong covalent bonds in SiO_2 but failed to mention anything regarding the energy requirements for breaking the intermolecular forces of attraction, IMFs, between liquid $SiCl_4$ molecules. Several answers compared the strength of the covalent bonds in both SiO_2 and $SiCl_4$ and many answers incorrectly stated that the structure of SiO_2 contained double bonds between the Si and O atoms.

(f) Many candidates gave the correct answer.

Question 4

(a) (i) The mechanism attracted many good answers. The common errors included: arrows from the negative charge (on the CN^- ion) instead of from the lone pair on the C atom, missing polarity, specifically missing the δ+ on the H (of H-CN), and incorrect attack of the intermediate by the CN^- ion.

(ii) Many answers stated that there were two CH_3 groups on one C atom in A but did not go further to explain the significance of this in terms of the lack of optical isomerism in A. Credit was given for stating that no chiral centre was present or that the central C atom was not bonded to four different atoms/groups.

(b) Candidates often stated that the mineral acids HCl or H_2SO_4 were required for the hydrolysis reaction of a CN group to a carboxylic acid but missed the requirement for the acid to be dilute or aqueous.

(c) (i) The equation was frequently correct. A common error was the omission of 2(H), from the equation, or using just 2H, without the brackets.

(ii) The name of compound C was well known.

(d) Most candidate answers stated that an orange precipitate was formed when propanone was reacted with 2,4-DNPH.

(e) A common answer was that 'Fehling's reagent only reacts with aldehydes', with no reference to any chemistry in this reaction. Fehling's reagent behaves as an oxidising reagent and ketones are not easily oxidised, hence, there is no reaction between Fehling's reagent and propanone.

(f) (i) Many candidate answers stated that the absorptions at 2850 – 2950 cm^{-1} were attributable to a C-H bond. As all three compounds in the question contained groups containing C-H bonds these compounds were indistinguishable using these absorptions.

(ii) Many candidates correctly identified the absorption at 2200 – 2250 cm^{-1}, which was unique to compound A, as it was the only compound containing a C≡N bond. As all three compounds, A, B and C contained an O-H bond, no credit was given for frequent mention of this absorption.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 31

Key messages

- Candidates should read the information given in the questions thoroughly: this applies to both the method and to the subsequent tasks.
- Candidates should be aware of the data section at the end of the paper and they should use the values given in that section appropriately.
- Candidates' knowledge of errors and ways of overcoming them in the various procedures was very limited.
- Supervisors carrying out the quantitative tasks should ensure that the accuracy of their results reflect the uncertainties of the apparatus used. Supervisors who omit results for a quantitative or qualitative procedure may disadvantage their candidates.
- Centres must contact Cambridge in advance of the examination if they are unable to source any chemical listed in the confidential instructions

General comments

Almost all candidates were able to complete the paper in the time allotted. A large majority were familiar with the quantitative procedures.

The use of 4-decimal place balances is inappropriate at this level.

Few candidates gained very high marks in the qualitative analysis question. A *lack of detail* led to marks being lost rather than deficiencies in practical skills and understanding.

It is advisable that the best practical chemist completes the Supervisor's script where possible.

Comments on specific questions

Question 1

Candidates were familiar with the thermometric technique required in this question. Some candidates had difficulty in drawing an appropriate graph of the results.

(a) Candidates were able to give the nine thermometer readings required. Some lost one of the marks for

- integer readings
- all readings ending in #.0
- readings to two decimal places (dp).

A large majority of candidates gained at least one mark for accuracy.

(b) (i) Most candidates labelled their axes correctly but some either did not use enough of the grid to gain the mark or used a difficult scale, *the data points should occupy at least half of the graph grid in both x- and y-directions*. And scales should be chosen *that allow the graph to be read easily, such as 1, 2 or 5 units to a 20 mm square;* In this question, 3 °C above their highest reading had to be included therefore starting the scale on the *y*-axis at 0 °C was inappropriate.

(ii) Points were usually accurately plotted though some were not correctly centred. Those selecting scales different from those given above were more likely to lose this mark.

(iii) Very few candidates gained the mark for drawing lines of best fit. The points leading up to the maximum temperature showed a distinct curve. Almost all candidates ignored this trend and drew a straight line.

(iv) Most candidates extrapolated their (curved or straight) lines correctly so gained this mark.

(v) Most candidates used a scale of two small squares to 1.0 cm^3 on the *x*-axis. This meant that giving the volume to 2 dp when the intersect was on a line was inappropriate. Values of .25 cm^3 and .75 cm^3 were credited where the intersect lay between the grid lines.

(c) (i) A large majority of candidates performing the calculation used the correct values. A significant number of these candidates gave the answer to one or two significant figures (sf) which was inappropriate. The concentration of FA 1 was given to 3 sf, thermometer readings were to 3 sf and burette readings were to 3 or 4 sf.

(ii) Most candidates gained at least one mark for correctly using the mole ratio of alkali to acid. Slightly fewer gained the second mark as not all used their volume of **FA 2** from **(b)** but used 40.00 cm^3 instead.

Question 2

Not all candidates read the rubric carefully. Questions are worded to help candidates select appropriate data for their calculations so should not be ignored.

(a) (i) Candidates should be encouraged to draw a table for their results prior to carrying out the method. This way there would be less chance of omitting balance readings or calculated values. A column headed with ‘mass/g’ or ‘mass (g)’ would ensure all data was covered by the correct unit. The heading for the final mass of flask and contents after fizzing had ceased was often incomplete.

(ii) Almost all candidates who recorded all four balance readings did so to a consistent number of dp.

(iii) Almost all candidates correctly calculated the mass of **FA 3** added. Fewer recorded the correct theoretical total initial mass.

(iv) Some did not record the calculated mass of carbon dioxide lost in the table. However, this was credited from a correct value shown in **(b)(i)**.

(v) Most candidates gained the mark for accuracy.

(b) (i) Many candidates gained this mark. Loss of the mark was usually owing to recording the amount of CO_2 evolved to 1 or to 5 sf which did not reflect the accuracy with which the procedure could be carried out given the apparatus used. The other relatively common error was to divide the mass of CO_2 by 24 dm^3.

(ii) Most candidates used 106 appropriately and so gained the first mark. Some did not use their answer to show that the Na_2CO_3 was in excess. Others either did not link moles of CO_2 with moles of acid or else used the value from **1(c)(ii)** without appreciating that this was for a different volume of sulfuric acid.

(iii) The majority of candidates gained this mark.

(c) (i) Many candidates scored 0 in this question. Candidates carrying out the procedure in **(a)** should have noted the rapid effervescence on adding Na_2CO_3 to the acid. Had the reaction mixture been in a small beaker some of the liquid contents would have been lost in addition to the gas.

(ii) Very few candidates gained more than one mark in this question.

1 A minority of candidates noted the low M_r of hydrogen but very few of these went on to link it to percentage error. Many more candidates tried to answer in terms of reactivity of Mg, or by stating that no CO_2 being produced made the method impossible, or in terms of safety issues with hydrogen.

2 More candidates noted that the low solubility of the calcium sulfate formed would inhibit further reaction. However, some thought that the insolubility of calcium sulfate was a problem as it would trap the carbon dioxide in the flask. Others suggested that calcium carbonate would not react with sulfuric acid without enlarging on their answer.

(d) Candidates also found this question challenging. Those not multiplying their uncertainty by 2 were unable to access the mark. A few candidates mistakenly used one of their balance readings as the denominator rather than the mass of **FA 3**.

Question 3

Answers in this section of the paper suggested that few candidates had read the Qualitative analysis instructions at the start of the question. Most candidates were able to access marks in the more familiar parts of the question.

(a) (i) Many candidates missed recording the initial colour of the crystals or claimed they were black instead of dark purple. More noted the change to a black solid residue. Although only a minority of candidates carried out gas tests some mistakenly claimed a white ppt with limewater or litmus turning blue. However, some noted a glowing splint relighting so gained one of the marks available.

(ii) Many candidates were able to give sufficient correct observations to access at least one mark.

Test 1: those suggesting a ppt had formed could not access the mark. The colour change of the solution from purple to pale yellow was rarely seen as many suggested the solution became colourless.

Test 2: some only commented on the solution being decolourised or that effervescence was seen. Both observations were creditworthy. The initial instructions state that a suitable test should be carried out to allow identification of the gas formed. Only a minority recorded a glowing splint relighting.

(iii) Some candidates noted the green colour forming though some lost the mark by describing it as solid. A common error was to report the formation of a black or purple solution instead.

(b) Most candidates were able to gain at least one of the three marks available. Test 3 caused candidates most problems. Errors included describing the precipitate formed on adding NaOH(aq) as yellow- this colour does not appear in the Qualitative analysis notes. A further observation of the effect of adding excess NaOH(aq) is expected. Good candidates noted both the insolubility of the ppt and its darkening (to brown) on standing. The colour of the ppt would have darkened considerably on addition of H_2O_2(aq) but few candidates noted this. Some candidates failed to note the fizzing of the mixture or to test the gas.

(c) Few candidates were able to access more than one mark. Some described the addition of a solution to a solid as formation of a precipitate.

Test 1: A frequent error in Test 1 was to describe the mixture as a black solution. A few candidates correctly recorded no change.

Test 2: credit was given for a gas turning litmus red (owing to fumes of HCl) as the formation of sufficient chlorine to bleach the paper in a short time may not have been evident. Some false results of gas tests were recorded with subsequent incorrect conclusions of H_2 or O_2.

Test 3: more candidates were able to gain credit here as many noted the fizzing and some correctly identified the gas as oxygen.

(d) (i) Many candidates correctly concluded the metal is manganese, Mn. Those writing Mn^{2+} could not access the mark as the ion must be part of a compound and not a metal. The most common incorrect metal given was iron, Fe. Some candidates suggested a non-metal such as sulfur.

(ii) Very few candidates gained both marks in this part. Many did not appear to understand the question as they provided 'ions' such as Mn^{7+} (which cannot exist in a compound) or wrote formulae of compounds such as $KMnO_4$. The oxidation state in this case should have been written as (+) VII or (+) 7. Another error was to give the oxidation state of (+) II/(+) 2 for both **FA 5** and **FA 6** showing the information given at the start of the question had been either forgotten or ignored.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 33

Key messages

- Candidates should read the information given in the questions thoroughly: this applies to both the method and to the subsequent tasks.
- Centres must contact Cambridge in advance of the examination if they are unable to source any chemical listed in the confidential instructions. If a hydrated salt is specified, the hydrated salt should be used.
- Candidates should be aware of the data section at the end of the paper and they should use the values given in that section appropriately.
- Candidates knowledge of errors and ways of overcoming them in the various procedures was very limited.
- Supervisors carrying out the quantitative tasks should ensure that the accuracy of their results reflect the uncertainties of the apparatus used. Supervisors who omit results for a quantitative or qualitative procedure may disadvantage their candidates.

General comments

Almost all candidates were able to complete the paper in the time allotted and most candidates appeared to be familiar with the quantitative procedures.

Candidates should use the wording found in the Qualitative analysis notes section of the paper to answer questions on qualitative analysis.

It is advisable that the best practical chemist at each centre completes the supervisor’s script where possible.

Balance readings given to one decimal place are not acceptable. If balances to this precision are the only balances available, then this should be noted in the supervisor report.

Comments on specific questions

Question 1

(a) (i) Headings were provided with units displayed correctly. However, candidates should be aware that each heading must be distinct from the others so that each weighing can be unambiguously identified. The most common error was that candidates did not distinguish between the mass of the conical flask and its contents at the start and the end of the experiments.

(ii) Precision of recording was completed well. Candidates should ensure that numbers are clear and legible. Where a reading has been changed, the original reading should be clearly crossed out.

(iii) Most candidates followed the method provided and as a result scored this accuracy mark.

(b) (i) Only the more able candidates selected the correct data from their results for this calculation.

(ii) Many candidates used the moles of acid rather than the moles of carbon dioxide produced, despite the question stating that the acid was in excess. Some candidates gave an answer to five significant figures rather than round to an appropriate number of significant figures.

(c) (i) More able candidates correctly linked a higher M_r with a lower number of moles of carbon dioxide but very few candidates gave a full explanation including one of the acceptable reasons for a lower mass of carbon dioxide being released.

(ii) The link between the density of a gas and how easily it escapes from the reaction vessel was not understood by most candidates.

(d) Many candidates would benefit from a greater discussion of percentage uncertainty and its calculation. The error is doubled if the value results from the difference between two readings.

Question 2

(a) Candidates were well prepared for the titration procedure but should be reminded that the burette readings for the rough titre must be recorded either in the space provided or clearly labelled in the main titration results table.

Some centres experienced problems with the titration due to the use of anhydrous sodium carbonate rather than hydrated sodium carbonate. Issues with the supply of required chemicals should be reported to Cambridge in advance of the examination. The use of anhydrous sodium carbonate generated a solution that was too dilute and required greater than 50 cm^3 for an end-point to be reached. Candidates were not disadvantaged on this occasion however centres should be reminded that all issues of this type must be reported on the supervisor report form.

(b) The mean values were calculated correctly and given to the appropriate precision.

(c) (i) Most candidates gave values to an appropriate number of significant figures. It is worth noting that it is sometimes necessary to add trailing zeros to provide the correct precision.

(ii) This calculation was challenging for many candidates with a significant number missing the fact that it was necessary to divide by the M_r of HCl.

(iii) Errors are always carried forward so candidates should be encouraged to continue with the calculation even if it seems to generate improbable results. Often this result can be used to correct earlier parts of the calculation. Many candidates missed one of the two calculation steps required in this question part.

(iv) Some candidates used their mass of **FA 1** from **Question 1** rather than 15.50 g as given in the stem.

(v) This question was well answered by those candidates who had an answer to **2(c)(iv)** greater than 124. Candidates should be encouraged to check the question for guidance as to whether or not the final answer should be given as an integer.

(d) Common errors included heating **FA 3** (a solution) rather than **FA 1**, stating that the heating would remove carbon dioxide (with or without loss of water) and reference to drying, which alone was not sufficient. To ensure that the method is as accurate as possible, **FA 1** should be heated to constant mass to remove all the water – not just until no further change.

Question 3

(a) (i) The instruction to identify any gas produced was often ignored. Some candidates did test the gas produced with limewater, but the test result was incorrectly described. A white precipitate is given as the result in the Qualitative analysis notes, and this is the only acceptable answer. Many candidates suggested the presence of ammonia. Many candidates did not state the initial colour of the solid. The movement of the solid and the presence of condensation were also frequently missed.

(ii) The presence of effervescence suggested that some candidates had not heated **FA 6** for long enough. Many candidates correctly observed a blue solution. This observation was missed by those who perhaps did not allow their final mixture to settle after shaking.

(iii) This question proved to be very challenging for most candidates. Where candidates did correctly identify the compounds involved in the reaction, many lost the mark due to missing or incorrect state symbols.

(b) (i) This question was a series of five separate tests. Observations were described well overall, however, some candidates appeared to have sequentially added the reagents to the same test-tube and had therefore not followed the instructions. Candidates should always refer to the Qualitative analysis notes when describing the observations from tests listed in the notes.

The reaction in Test 5 was quite slow and some candidates did not leave the test-test tube to stand as instructed and therefore did not describe the deposition of solid copper.

Candidates should be aware that marks may be lost if further tests are attempted when the instructions clearly state the opposite.

(ii) Most candidates observed a blue-black colour in Test 4. The indication of iodine is stated in the Qualitative analysis notes and many candidates recognised that the anion was likely to be iodide and carried out appropriate further tests.

(iii) Very few candidates identified reactions 4 and 5 as the redox reactions.

(iv) This was a challenging question for most candidates. Only the more able candidates gave a fully correct equation.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 34

Key messages

- Candidates should read the information given in the questions thoroughly: this applies to both the method and to the subsequent tasks.
- Candidates should be aware of the data section at the end of the paper and they should use the values given in that section appropriately.
- Candidates knowledge of errors and ways of overcoming them was very limited.
- Supervisors carrying out the quantitative tasks should ensure that the accuracy of their results reflect the uncertainties of the apparatus used. Supervisors who omit results for a quantitative or qualitative procedure may disadvantage their candidates.

General comments

Almost all candidates were able to complete the paper in the time allotted.

Answers written either in pencil or first in pencil then overwritten in pen are sometimes difficult to decipher.

Most candidates appeared to be familiar with both the quantitative procedures. Centres are reminded that balance readings given to one decimal place are not acceptable. If balances to this precision are the only balances available, then this must be noted in the Supervisor report.

Candidates should take time to read the introductory notes for the qualitative analysis question and use the wording found in the Qualitative analysis notes section of the paper where appropriate.

It is advisable that the best practical chemist completes the Supervisor's script where possible.

Comments on specific questions

Question 1

Most candidates appeared to be well practiced 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) Candidates should be reminded that burette readings for the rough titre must be recorded either in the space provided or clearly labelled in the main titration results table. Unlike the readings for the accurate titres, rough readings do not need to be shown to #.#0 or #.#5. Most candidates recognised that the final titre needs to be concordant (within 0.10 cm^3 of another) and many gained all three marks for accuracy.

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

(c) (i) Owing to the concentrations of reactants shown in **(a)** and the precision of the apparatus used, answers for **(ii)** and **(iii)** should be given to 3 or 4 significant figures (sf). Many candidates gave at least one answer to either 2 or 5 sf so lost the mark.

(ii) Almost all candidates gained the first mark but few gained the second mark. Candidates are reminded to read the method carefully so they understand what they are asked to calculate.

(iii) Some candidates were awarded this mark even though their previous answer was incorrect, either as an 'error carried forward' or by calculating the correct answer using a different route.

(iv) Very few candidates were able to calculate the initial concentration of iodine in the reaction mixture and therefore the average rate of reaction correctly. Reading the information at the start of the question carefully is advised. The majority were able to provide the correct units for rate to gain the second mark available.

(d) Few candidates were able to provide a correct answer for this question. The addition of the indicator later in the titration rather than at the start is unusual and centres should discuss with candidates why this is necessary.

(e) Only a small number of candidates were awarded this mark. To answer successfully, candidates needed to have read and considered the information given on page 2. Centres should provide opportunities, including using previous question papers, for candidates to discuss scenarios such as the one provided here.

Question 2

(a) Candidates should be encouraged to draw a table for their results before carrying out the method. This would avoid omitting balance readings or calculated values. A column headed with 'mass/g' or 'mass (g)' would ensure all data was covered by the correct unit. For mark **I**, a common error was use of 'mass of crucible + lid + **FB 4** after 1st/2nd heating'. After heating the solid is no longer **FB 4** and should be referred to as either 'residue' or 'contents after heating'. Candidates should also be reminded to distinguish between the two balance readings after heating. Mark **II** was usually awarded. Where candidates were not awarded mark **III**, the reason was sometimes failing to record the calculated mass of residue or, more frequently, confusing the mass of residue with the mass of water lost.

Most candidates successfully carried out the method and were awarded at least mark **IV** and often both **IV** and **V**.

(b) Calculation of moles of water was successfully carried out by most candidates. Many did not take account of the 2:1 ratio of water: $\mathbf{MA_2}$ when finding the formula mass of $\mathbf{MA_2}$. Candidates should be aware that reporting a quantitative answer to an appropriate number of significant figures is expected. In this case, each answer should be given to 2-4 significant figures.

(c) Most candidates correctly used silver nitrate to identify the halide present. Candidates that added hydrochloric acid at any point during the test invalidated the test and as such no marks were awarded. The halide is identified using either its name or formula. These should be correct, i.e. chloride (not chlorine) or Cl^- (not Cl alone).

(d) Many candidates demonstrated use of their answers for **(b)** and **(c)** to calculate the atomic mass of **M**. Some did not identify **M** correctly because either they did not choose a Group 2 metal or they did not choose the Group 2 metal with the closest atomic mass to their answer.

(e) Considering the effect of an error in the procedure is a regular feature of examinations of this component and candidates should be given plenty of opportunities to practise questions of this type.

Question 3

Overall candidates seemed less practiced answering the Qualitative analysis question than the Quantitative analysis ones. Centres should provide opportunities for candidates to make clear, concise observations of straightforward reactions and use of the Qualitative analysis notes.

(a) (i) A minority of candidates were awarded this mark although there were several observations that could have been made. Some candidates did describe the initial appearance of **FB 6** and its colour and state after heating. Candidates had the opportunity to consider the gas which may be produced upon heating **FB 6** because the identity of **FB 6** was provided but few tested for or correctly identified this gas.

(ii) For both Tests 1 and 2, a solid is mixed with a liquid. In both cases the result is a solution which has a different colour from the original liquid. A correct, concise observation for each test would be awarded the mark but few candidates were successful. Some candidates reported the solution was black. If a solution is very dark, gently shaking the tube and observing the solution running down the inner surface will reveal its colour.

(iii) Candidates should be aware that oxidation never takes place without reduction and vice versa.

(b) (i) From the information given in the question, candidates are expected to realise that the first part of Test 1 should indicate that **FB 7** includes one of the cations shown in section 1 of the Qualitative analysis notes. Candidates are advised to make good use of these notes when the opportunity arises. In the second part of this test, fizzing was reported by most candidates but most failed to test for or identify the gas produced.

In Test 2, some candidates reported an ‘opaque solution’ which is a contradiction in terms. Candidates should be aware of the definition of ‘precipitate’.

(ii) The Qualitative analysis notes were very useful for this question and many candidates chose the correct reagents and achieved the correct results. Candidates are reminded that the full name or formula of each reagent should be chosen, e.g. barium nitrate or $Ba(NO_3)_2$ rather than just ‘Ba^{2+}’. A small number of candidates inappropriately chose to use sulfuric acid to test the solubility of the precipitate produced.

(iii) Many candidates successfully answered this question. A very small number were not awarded the mark because they either wrote a name or mixed up the use of capital and lower-case letters in the formula written.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 35

Key messages

- Candidates should read the information given in the questions thoroughly: this applies to both the method and to the subsequent tasks.
- Candidates should be aware of the data section at the end of the paper and they should use the values given in that section appropriately.
- Candidates' knowledge of errors and ways of overcoming them in the various procedures was very limited.
- Supervisors carrying out the quantitative tasks should ensure that the accuracy of their results reflect the uncertainties of the apparatus used. Supervisors who omit results for a quantitative or qualitative procedure may disadvantage their candidates.
- Centres must contact Cambridge in advance of the examination if they are unable to source any chemical listed in the confidential instructions

General comments

Almost all candidates were able to complete the paper in the time allotted. A large majority were familiar with the quantitative procedures.

The use of 4-decimal place balances is inappropriate at this level.

Few candidates gained very high marks in the qualitative analysis question. A *lack of detail* led to marks being lost rather than deficiencies in practical skills and understanding.

It is advisable that the best practical chemist completes the Supervisor's script where possible.

Comments on specific questions

Question 1

Candidates were familiar with the thermometric technique required in this question. Some candidates had difficulty in drawing an appropriate graph of the results.

(a) Candidates were able to give the nine thermometer readings required. Some lost one of the marks for

- integer readings
- all readings ending in #.0
- readings to two decimal places (dp).

A large majority of candidates gained at least one mark for accuracy.

(b) (i) Most candidates labelled their axes correctly but some either did not use enough of the grid to gain the mark or used a difficult scale, *the data points should occupy at least half of the graph grid in both x- and y-directions*. And scales should be chosen *that allow the graph to be read easily, such as 1, 2 or 5 units to a 20 mm square;* In this question, 3 °C above their highest reading had to be included therefore starting the scale on the *y*-axis at 0 °C was inappropriate.

(ii) Points were usually accurately plotted though some were not correctly centred. Those selecting scales different from those given above were more likely to lose this mark.

(iii) Very few candidates gained the mark for drawing lines of best fit. The points leading up to the maximum temperature showed a distinct curve. Almost all candidates ignored this trend and drew a straight line.

(iv) Most candidates extrapolated their (curved or straight) lines correctly so gained this mark.

(v) Most candidates used a scale of two small squares to 1.0 cm^3 on the *x*-axis. This meant that giving the volume to 2 dp when the intersect was on a line was inappropriate. Values of .25 cm^3 and .75 cm^3 were credited where the intersect lay between the grid lines.

(c) (i) A large majority of candidates performing the calculation used the correct values. A significant number of these candidates gave the answer to one or two significant figures (sf) which was inappropriate. The concentration of FA 1 was given to 3 sf, thermometer readings were to 3 sf and burette readings were to 3 or 4 sf.

(ii) Most candidates gained at least one mark for correctly using the mole ratio of alkali to acid. Slightly fewer gained the second mark as not all used their volume of **FA 2** from **(b)** but used 40.00 cm^3 instead.

Question 2

Not all candidates read the rubric carefully. Questions are worded to help candidates select appropriate data for their calculations so should not be ignored.

(a) (i) Candidates should be encouraged to draw a table for their results prior to carrying out the method. This way there would be less chance of omitting balance readings or calculated values. A column headed with 'mass/g' or 'mass (g)' would ensure all data was covered by the correct unit. The heading for the final mass of flask and contents after fizzing had ceased was often incomplete.

(ii) Almost all candidates who recorded all four balance readings did so to a consistent number of dp.

(iii) Almost all candidates correctly calculated the mass of **FA 3** added. Fewer recorded the correct theoretical total initial mass.

(iv) Some did not record the calculated mass of carbon dioxide lost in the table. However, this was credited from a correct value shown in **(b)(i)**.

(v) Most candidates gained the mark for accuracy.

(b) (i) Many candidates gained this mark. Loss of the mark was usually owing to recording the amount of CO_2 evolved to 1 or to 5 sf which did not reflect the accuracy with which the procedure could be carried out given the apparatus used. The other relatively common error was to divide the mass of CO_2 by 24 dm^3.

(ii) Most candidates used 106 appropriately and so gained the first mark. Some did not use their answer to show that the Na_2CO_3 was in excess. Others either did not link moles of CO_2 with moles of acid or else used the value from **1(c)(ii)** without appreciating that this was for a different volume of sulfuric acid.

(iii) The majority of candidates gained this mark.

(c) (i) Many candidates scored 0 in this question. Candidates carrying out the procedure in **(a)** should have noted the rapid effervescence on adding Na_2CO_3 to the acid. Had the reaction mixture been in a small beaker some of the liquid contents would have been lost in addition to the gas.

(ii) Very few candidates gained more than one mark in this question.

1 A minority of candidates noted the low M_r of hydrogen but very few of these went on to link it to percentage error. Many more candidates tried to answer in terms of reactivity of Mg, or by stating that no CO_2 being produced made the method impossible, or in terms of safety issues with hydrogen.

2 More candidates noted that the low solubility of the calcium sulfate formed would inhibit further reaction. However, some thought that the insolubility of calcium sulfate was a problem as it would trap the carbon dioxide in the flask. Others suggested that calcium carbonate would not react with sulfuric acid without enlarging on their answer.

(d) Candidates also found this question challenging. Those not multiplying their uncertainty by 2 were unable to access the mark. A few candidates mistakenly used one of their balance readings as the denominator rather than the mass of **FA 3**.

Question 3

Answers in this section of the paper suggested that few candidates had read the Qualitative analysis instructions at the start of the question. Most candidates were able to access marks in the more familiar parts of the question.

(a) (i) Many candidates missed recording the initial colour of the crystals or claimed they were black instead of dark purple. More noted the change to a black solid residue. Although only a minority of candidates carried out gas tests some mistakenly claimed a white ppt with limewater or litmus turning blue. However, some noted a glowing splint relighting so gained one of the marks available.

(ii) Many candidates were able to give sufficient correct observations to access at least one mark.

Test 1: those suggesting a ppt had formed could not access the mark. The colour change of the solution from purple to pale yellow was rarely seen as many suggested the solution became colourless.

Test 2: some only commented on the solution being decolourised or that effervescence was seen. Both observations were creditworthy. The initial instructions state that a suitable test should be carried out to allow identification of the gas formed. Only a minority recorded a glowing splint relighting.

(iii) Some candidates noted the green colour forming though some lost the mark by describing it as solid. A common error was to report the formation of a black or purple solution instead.

(b) Most candidates were able to gain at least one of the three marks available. Test 3 caused candidates most problems. Errors included describing the precipitate formed on adding NaOH(aq) as yellow- this colour does not appear in the Qualitative analysis notes. A further observation of the effect of adding excess NaOH(aq) is expected. Good candidates noted both the insolubility of the ppt and its darkening (to brown) on standing. The colour of the ppt would have darkened considerably on addition of H_2O_2(aq) but few candidates noted this. Some candidates failed to note the fizzing of the mixture or to test the gas.

(c) Few candidates were able to access more than one mark. Some described the addition of a solution to a solid as formation of a precipitate.

Test 1: A frequent error in Test 1 was to describe the mixture as a black solution. A few candidates correctly recorded no change.

Test 2: credit was given for a gas turning litmus red (owing to fumes of HCl) as the formation of sufficient chlorine to bleach the paper in a short time may not have been evident. Some false results of gas tests were recorded with subsequent incorrect conclusions of H_2 or O_2.

Test 3: more candidates were able to gain credit here as many noted the fizzing and some correctly identified the gas as oxygen.

(d) (i) Many candidates correctly concluded the metal is manganese, Mn. Those writing Mn^{2+} could not access the mark as the ion must be part of a compound and not a metal. The most common incorrect metal given was iron, Fe. Some candidates suggested a non-metal such as sulfur.

(ii) Very few candidates gained both marks in this part. Many did not appear to understand the question as they provided ‘ions’ such as Mn^{7+} (which cannot exist in a compound) or wrote formulae of compounds such as $KMnO_4$. The oxidation state in this case should have been written as (+) VII or (+) 7. Another error was to give the oxidation state of (+) II/(+) 2 for both **FA 5** and **FA 6** showing the information given at the start of the question had been either forgotten or ignored.

CHEMISTRY

Paper 9701/36
Advanced Practical Skills 36

Key messages

- Candidates should read the information given in the questions thoroughly: this applies to both the method and to the sequent tasks.
- Candidates should be aware of the data section at the end of the paper and they should use the values given in that section appropriately.
- Candidates knowledge of errors and ways of overcoming them was very limited.
- Supervisors carrying out the quantitative tasks should ensure the accuracy of their results reflect the uncertainties of the apparatus used check the relevant parts of the qualitative question have been addressed.
- Centres must contact Cambridge in advance of the examination if they are unable to source any chemical listed in the confidential instructions.

General comments

Almost all candidates were able to complete the paper in the time allotted.

A large majority of candidates appeared familiar with the quantitative procedures.

Use of 4-decimal place balances is inappropriate at this level.

Few candidates gained high marks in the qualitative analysis question due to a lack of detail in their answers.

It is advisable that the best practical chemist completes the supervisor's script where possible. Supervisors who omit to record results for a quantitative or qualitative procedure may disadvantage their candidates.

Comments on specific questions

Question 1

Many candidates gained high marks for this question. Not all candidates used the molar gas volume given on page 11 of the paper. The calculation section proved straightforward for many candidates.

(a) The majority of candidates were able to access at least two of the four marks available. A few only recorded the volume of gas collected in **(b)** so did not follow the instructions given in the method. Most candidates recorded both balance readings consistently to 2 or to 3 decimal places (dp) and correctly calculated the mass of **FB 1** used. Most 250 cm^3 measuring cylinders are calibrated at 2 cm^3 so the volume readings were expected to be given to 1 cm^3. Examiners were alerted to the existence of measuring cylinders calibrated at 5 cm^3 so candidates using these should not be penalised. A few candidates lost a mark owing to using ml rather than cm^3 for their volumes. Many candidates gained the mark for accuracy.

(b) (i) Most candidates understood that their answers needed to be recorded to 2 – 4 significant figures (sf).

(ii) The majority of candidates correctly calculated the amount of carbon dioxide collected in **(a)**. A small number failed to convert cm^3 to dm^3. The most common error was dividing by 44.

(iii) The majority of candidates used the equation given on page 2 to answer the first part of this question correctly. Most candidates correctly multiplied their answer by 106.

(iv) The majority of candidates were awarded the mark for calculating the percentage purity of sodium carbonate. However, when a candidate's mass in **(b)(iii)** was incorrect and greater than the mass of **FB 1,** they usually inverted the equation.

(c) Candidates tended to answer this question in two main ways. The expected response was to describe some means of keeping the reactants separated until the bung was inserted (a sketched method was accepted). However, credit was also given to those suggesting a method of reducing the rate of reaction as this would have reduced, though not minimised, the loss of carbon dioxide.

(d) Some candidates ignored the instruction that use of another liquid would not be credited. Others either suggested using hot water or saturating the water with CO_2 before the experiment. The most common incorrect answers were to use colder water or to use a gas syringe.

(e) This question was less well answered. Those not multiplying their uncertainty by 2 were unable to access the mark. Some candidates used one of their balance readings as the denominator rather than the mass of **FB 1**.

Question 2

Excellent answers to this question there seen. Not all candidates read the instructions in the method carefully. Information given is usually required at some stage of the question so should not be ignored.

(a) Candidates are encouraged to draw a table for their results prior to carrying out the method. A column headed with 'mass/g or (g)' would ensure all data is covered by the correct unit. Common errors in the headings included 'mass of crucible + lid + **FB 3** after 1st/2nd heating', failure to distinguish between the two balance readings after heating and omitting the mass after the second heating. Some candidates did not heat **FB 3** sufficiently strongly the first time as there was a greater than 0.05 g loss in mass on the second heating. Almost all candidates recorded their balance readings to the same number of dp and correctly calculated the mass of **FB 3** used but some candidates confused mass of residue with mass loss. Many candidates gained at least one of the two marks for accuracy.

(b) (i) Many candidates gained this mark. Loss of the mark was usually due to recording the amount of CO_2 evolved to 1 or to 5 sf which did not reflect the accuracy with which the procedure could be carried out given the apparatus used.

(ii) Many candidates gained this mark. Loss of the mark was usually owing to use of 84 as the relative formula mass of $MgCO_3$.

(iii) Those candidates using their answer to **(b)(ii)** correctly usually gained the mark. A minority of candidates gave answers that did not total to the expected 100 per cent.

(c) (i) Almost all candidates correctly recorded a pH ≥ 9 but fewer noted the rise in temperature on adding water. When adding a few drops of water, the crucible would be warmer to the touch and there would be some condensed water vapour seen above the residue.

(ii) Some candidates suggested water was added to $MgCO_3$ and gained the mark for the species involved in the reaction. Fewer candidates gained the mark for giving correct state symbols and for the correct direction (+ or −) of ΔH. Candidates gained the mark as error carried forward (ecf) from suggesting the reaction in **(c)(i)** was endothermic.

(iii) Credit was awarded to those suggesting the use of a **named** acid. Candidates should be aware that 'CO_2 is formed' is a conclusion whereas 'effervescence/fizzing/bubbling' is an observation and the expected answer. Those candidates who suggested passing the gas into limewater were credited provided they gave the observation of 'white ppt' formed. Some candidates misunderstood the question and answered in terms of heating to constant mass.

Question 3

Candidates appear to be less familiar with qualitative analysis questions. In a question part where 4 marks are available more than one or two observations are required.

(a) This question asked for conclusions to be drawn as well as observations to be recorded. There were eight possible observations. Candidates were expected to heat the mixture gently at first and to note that water is driven off, a gas turning red litmus blue is formed, sublimation occurs and a liquid forms. Gentle heating gave rise to ammonia being identifiable. The stronger heating section led to some bubbling/boiling of the liquid (not to be confused with fizzing or effervescence), white smoke and a white (or grey) residue being formed. The white smoke turned blue litmus red showing it is acidic. Suggesting the gas was hydrogen or oxygen was incorrect. Very few candidates gained more than 2 of the 4 marks available.

(b) (i) Not all candidates made a solution of **FB 4** before adding the reagents.

Test 1: most candidates gave the expected observations. It is important that candidates make it clear that they are testing for a gas on warming the resultant mixture with aluminium foil.

Test 2: many candidates made correct observations.

Test 3: many candidates made correct observations. However, in both Tests 1 and 2 some reported ‘white solution’ which was incorrect.

Test 4: many candidates made correct observations though a few mistakenly reported a gas being given off.

(ii) Most candidates that gave correct observations in **(b)(i)** were able to gain both available marks. However, the evolution of ammonia in Test 1 gave rise to some candidates suggesting the presence of either or both NO_2^- and NO_3^-. Some candidates reporting a coloured precipitate with aqueous silver nitrate, or that the precipitate with the aqueous barium salt was soluble in nitric acid, suggested Br^-, I^- or SO_3^{2-}. As the observations were incorrect these conclusions could not be credited. A small number of candidates confused anions with cations.

(iii) At this stage of **Question 3** candidates should be concluding that the possible cations in **FB 4** are NH_4^+, Al^{3+} and Zn^{2+}. While it is not essential to test a solution of **FB 4** with NaOH(aq) and warm to be able to confirm the presence of NH_4^+, **FB 4(aq)** is needed when distinguishing between Al^{3+} and Zn^{2+}. Credit was only given for testing the solution with aqueous ammonia when finding **FB 4** also contained Zn^{2+}. Some candidates who assumed that **(b)(i)** Test 1 showed the presence of a nitrate did not test for the ammonium ion.

Candidates at this level are expected to lay out their tests, observations and conclusions in a clear format. As conclusions are not frequently required in a ‘test/observations’ table some leniency was given for recording the conclusions in a separate section.

CHEMISTRY

Paper 9701/41
A Level Structured Questions 41

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

CHEMISTRY

Paper 9701/42
A Level Structured Questions 42

Key messages

- Candidates who had learnt definitions carefully, rather than attempting a description, scored more marks.
- Candidates must ensure their handwriting is legible, for example, exothermic or endothermic and numbers 1 or 2 and 4 or 9. If the exact word or number is not clear, marks are not awarded.
- 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 utilised. A comment noting this is helpful.
- Answers to calculations should be given to a minimum of 2 sf but 3 sf is preferred. 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.
- This paper featured some questions where the numerical answer was given in the question and candidates had to show this is true. It is essential that every step in a candidate's calculation is shown for such questions.

General comments

Both care and the correct following of convention is needed when writing the formulae of substances.

Working should be shown when answering questions involving calculation.

Most candidates were able to work through to the end of the paper.

Many candidates performed well in the following areas:

- correct rounding of answers at the end of a calculation
- annotation of calculations to explain each step
- the use of three-dimensional bonds to show the shape of a complex
- describing the stages of a reaction mechanism.

Comments on specific questions

Question 1

(a) (i) This question was found to be difficult by many candidates. The key information that two half-life periods have elapsed was often missed.

(ii) This question was answered well.

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

(iv) Most candidates were able to use their rate equation and the value of *k* to calculate the initial rate and give correct units.

(b) (i) This question discriminated well. A full explanation was required. Partial answers such as 'has vacant d-orbitals' did not score.

(ii) This question was answered well.

(iii) This question was answered well with the terms ‘adsorption’ and ‘desorption’ being used correctly. Many candidates stated, ‘the bonds **between** reactants are weakened’. This did not score, as it implies the weakening of intermolecular forces between neighbouring NO_2 molecules. The statement ‘the bonds **within** NO_2 molecules are weakened’ is a much better description.

(iv) Many unbalanced equations, and equations with SO, were seen.

(c) This was a difficult question. Candidates who were able to deduce that BiO^+ is the only oxidising agent on the list strong enough to oxidise H_2SO_3 to SO_4^{2-} often went on to score all three marks.

Question 2

(a) Most candidates were awarded some marks for this question. The mention of the importance of either the decrease in ionic radius **or** the increase in ionic charge was much more common than the mention of **both**.

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

(ii) A commonly seen error was the reference to ΔH_{hyd} $MgCl_2$ rather than ΔH_{hyd} Mg^{2+} + $2\Delta H_{hyd}$ Cl^-.

(iii) Some candidates were unable to select the correct data, while others did not double the value of –364.

(c) Answers to questions about the definition of entropy are improving. ‘The number of possible arrangements of particles and their energy in a system’ is a good answer and was frequently seen.

(d) This question was answered well.

(e) (i) The significance of the positive value of ΔG was understood by many candidates.

(ii) Many candidates realised that ΔG will become less positive since ΔS is positive and that this will make **Z** more soluble. The terms exothermic and endothermic should not be used when describing ΔG.

Question 3

(a) (i) This question was answered well by many candidates. It is essential for candidates to explain what they are doing. $10^{-12.35}$ did not score a mark, but $(H^+) = 10^{-12.35}$ did score a mark. 1.65 did not score a mark, but pOH = 1.65 did score a mark.

(ii) Candidates had to realise that the concentration they are given is for OH^-, therefore $[Ca^{2+}]$ is half this value. Writing the expression for solubility product is the correct way for a candidate to start their answer.

(iii) Candidates found this question one of the most difficult on the paper. The observation that a white precipitate forms was rarely seen, as was the identity of this precipitate, calcium hydroxide. The precipitation of calcium hydroxide explains the decrease in pH.

(iv) Candidates who recognised that they were being asked to explain the trend in solubility of the Group 2 sulfates scored well.

(b) (i) Candidates found this equation surprisingly difficult. Many candidates did not know that hydrogen gas is formed.

(ii) A conjugate acid–base pair can only differ by a single H^+ ion. Pairs that differ by one or more Ca^{2+} ions are not conjugate acid–base pairs. A small number of answers included a second conjugate acid–base pair such as H_3O^+ and H_2O.

(iii) This question was answered well.

(iv) It was necessary to realise that in 0.394 mol dm^{-3} calcium ethanoate the concentration of ethanoate ions is 0.788 mol dm^{-3}. Candidates who failed to do so could still score one mark.

(v) Two correct equations were often seen. Equations that began with $Ca(CH_3COO)_2$ were more difficult to complete and balance than equations that began with CH_3COO^-.

Question 4

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

(ii) Most candidates could answer this question correctly Some candidates lost the mark for showing the complex as $(Co(H_2O)_4(OH)_2)^{2+}$ or because they did not balance the equation for OH^- ions.

(iii) This mark was awarded to a minority of candidates. Ligand exchange was the most common answer however the description in the question makes clear this is an acid–base reaction.

(b) (i) This mark was awarded to most candidates.

(ii) This mark was awarded to most candidates.

(iii) Many candidates were awarded this mark. It was common to see the numbers 2 and 3 the wrong way round.

(iv) This mark was awarded to most candidates. Some candidates appear to have misread the question, resulting in their answer ‘d-orbitals that have the same energy.’

(c) (i) This question discriminated well. The two most frequently seen errors were:

- equations that did not use the 1:5 stoichiometry given in the question
- equations that were unbalanced for hydrogen, or oxygen, or both.

(ii) Most candidates were able to calculate the number of moles correctly.

(iii) Many candidates were able to calculate the M_r and the value of n correctly. Some candidates did not appreciate that their answer to 4cii is for a 25.0 cm^3 sample. The 4.18 g given in the question was dissolved in 250 cm^3 of solution **F**, so only one tenth of solution **F** had been titrated.

Question 5

(a) A significant number of candidate responses show the ionic charges outside the last set of square brackets: $[Ni(en)_3]^{2+}$. The correct place to put the charge is inside an extra set of square brackets: $[[Ni(en)_3]^{2+}]$.

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

(ii) This question was answered well.

(c) This question was answered well. Candidates use of three-dimensional bonds has improved significantly.

Question 6

(a) (i) Common errors were $ClOOCOOCl$ and $HOOCCOCl$.

(ii) PCl_3 and PCl_5 were often seen.

(b) The expected answers were acidified $KMnO_4$ and oxygen. Few candidates thought of combustion, and oxygen was rarely seen. Credit was given for other oxidising agents that would be effective e.g. acidified $K_2Cr_2O_7$.

(c) This question discriminated well. A well-reasoned and logical answer was required and many candidates scored two for:

- stating that each ethanedioic acid molecule has more electronegative oxygen atoms than each methanoic acid molecule
- stating that this electron-withdrawing effect either weakens the O–H bond or stabilises the conjugate base.

Candidates must make it clear which bond is weakened. O–H is unambiguous whereas –O–H is ambiguous

(d)(i) This mark was awarded to many candidates. Acceptable ways of showing the answer include:

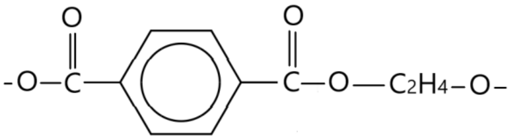
and

Some candidates have started using a representation such as that shown below.

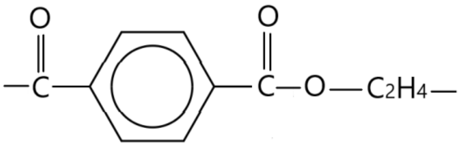
This approach lost the mark and should be strongly discouraged.

(ii) The reagents for steps 1 and 2 were generally well known. Some candidates lost the mark for step 2 because they wrote 'hot alkaline KMNO$_4$' or 'hot alkaline KmNO$_4$'. The use of upper case and lower-case letters in chemical formulae is important and should always be correct.

(iii) Many candidates drew the displayed formula of the ester linkage correctly. A smaller number gave exactly one repeat unit. Two repeat errors are shown below.



This diagram has one oxygen atom too many.



This diagram has one oxygen atom too few.

(iv) This question was answered well.

Question 7

(a) This mark was awarded to most candidates.

(b)(i) Before step 1 takes place the pair of electrons is in the ring of delocalised π electrons. After step 1 has taken place the pair of electrons is forming a σ bond between a carbon atom and the chlorine atom.

(ii) Before step 2 takes place the pair of electrons is forming a σ bond between a carbon atom and a hydrogen atom. After step 2 has taken place the pair of electrons is in the ring of delocalised π electrons.

(c) This question discriminated well. Five of the carbon atoms in the ring are still sp^2 hybridised. Only the carbon atom where the chlorine atom has attached is sp^3 hybridised.

(d) This question was answered well.

(e) Many candidates ignored the instruction to use formulae.

(f) (i) This question discriminated well. The major organic product being identified as ethene or as ethanoic acid was a common incorrect answer.

(ii) This question discriminated well. Excellent answers were seen. Some characteristics of these answers were:

- identifying that the lone pair of electrons that is delocalised into the benzene ring comes from the chlorine atom
- identifying the bond that has partial double bond nature as the carbon to chlorine bond.

Question 8

(a) This question required a very specific answer as described in the syllabus.

(b) This question was answered well.

(c) The term ‘enantiomers’ was known by a small number of candidates.

(d) The term ‘racemic mixture’ was known by a small number of candidates.

(e) This question required a very specific answer as described in the syllabus.

(f) This question discriminated well. Many candidates did not understand that when serine is dissolved in D_2O, only the CH_2 and CH protons will show peaks in the proton NMR spectrum. Candidates were expected to describe these protons clearly and unambiguously in column one of the table. $HOCH_2$ is not clear and unambiguous as this answer could refer to either the OH proton or the CH_2 protons.

(g) This question discriminated well. Four was a commonly seen error, suggesting that the proton in the –COOH group was not included.

(h) This question tested very specific knowledge. Candidates who understood that the $–NH_2$ group is protonated at low pH, and that the –COOH group is deprotonated at high pH, usually scored at least two marks.

CHEMISTRY

Paper 9701/43
A Level Structured Questions 43

Key messages

- Candidates must ensure their handwriting is legible.
- If a candidate wishes to change their answer, the original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations, ionic equations and half-equations should always be balanced for both substances and charge were appropriate.

General comments

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

The correct convention is needed when writing the formulae of substances. For example, potassium manganate(VII) should be written $KMnO_4$ and not KmNO4 or $KMNO_4$.

Comments on specific questions

Question 1

(a) (i) Candidates found this question difficult. Many identified compounds rather than the ions.

(ii) This definition was well known. A few candidates incorrectly stated that a buffer solution kept the pH of the solution constant.

(iii) This question discriminated well. Candidates who gave ionic equations found them easier to balance, many other equations were unbalanced for sodium ions.

(iv) This ion was not known by the majority of candidates

(b) (i) Candidates performed well on this question. Some did not fully explain the calculation so only received partial credit.

(ii) This question proved difficult for some candidates. A clear explanation was needed which stated that there were two moles of hydroxide ions in one mole of compound **E**.

(iii) This question was well answered. Most candidates correctly calculated the relative formula mass of **E** and identified compound **E** as barium hydroxide.

(c) Most candidates calculated the K_{sp} of magnesium hydroxide correctly. The most common error was not to multiply the concentration of hydroxide ions by two.

(d) To answer this question successfully, candidates had to state the changes that occur in ΔH_{hyd} and ΔH_{latt}, for compound **E** compared to magnesium hydroxide. The trend in Group 2 hydroxides was accepted as an alternative answer. This leads into the effect on the enthalpy change of solution. Many correct answers were seen. Common errors included:

- ○ stating ΔH_{hyd} changes more than ΔH_{latt} and
- ○ discussing the difference in ionic radii of Mg^{2+} and Ba^{2+} only.

Question 2

(a) Most candidates knew that enthalpy change of hydration becomes less negative down the group, but some did not explain that this was because of the size of the halide ion increasing. Fewer candidates related the anion size to its attraction to water molecules.

(b) (i) A majority of candidates answered this question correctly.

(ii) This question was well answered. Many candidates were able to correctly state the five other enthalpy changes. Some candidates did not link the enthalpy change to a species or included an incorrect enthalpy change such as the second electron affinity for fluorine or the lattice energy of CaF_2.

(iii) This definition was well known. Common errors were to state that energy was 'required' to form a lattice and that one mole of ionic compounds was formed from 'one mole' of gaseous ions.

(iv) Many candidates answered this question well. Common errors included:

- subtracting enthalpy change for process three from enthalpy change for process one, and
- stating the mathematical relationship: $\Delta H_{latt} = \Delta H_{hyd} - \Delta H_{sol}$.

(c) Candidates performed well on this question. The most common error was not dividing by two which gave an answer of –946.

(d) The definition of entropy was well known. Some candidates confused this with entropy change of reaction.

(e) This question was answered well. Most candidates could recall the Gibbs free energy equation. Some candidates had difficulty with the calculation and using the correct units for each of the species.

(f) This question discriminated well. Just stating that ΔG becomes more negative was insufficient. Candidates had to relate the effect of increasing temperature on $T\Delta S$.

Question 3

(a) (i) Most candidates gave the rate equation, rate = k[A][B], suggesting they had deduced this was a second-order reaction overall. Few candidates went on to correctly give the two other rate equations. Common errors were giving the other rate equations as third or fourth-order overall.

(ii) This question was well answered. Most candidates used one of their rate equations to correctly calculate the rate constant and its units.

(iii) This question discriminated well. Many candidates stated the half-life is not constant as it is a second-order reaction. A common error was suggesting that the half-life was too small to calculate.

(b) (i) The identity of the metal catalysts for the removal of NO_2 was not well known. Common errors included nickel, iron and chromium.

(ii) This question proved difficult for some candidates. Responses often lacked precision, missing some of the key ideas for the mode of action of a heterogeneous catalyst. Responses needed to be specific: adsorption, bonds weakening, desorption.

(iii) This question discriminated well. Many candidates lost marks by writing equations that were unbalanced for charge.

(iv) Most candidates gave the correct answer to this question.

(c) (i) This question proved difficult for many candidates. Some confused this definition with the explanation of why transition elements can form complex ions.

(ii) Many fully correct answers were seen. Some candidates used Fe^{2+} and Fe^{3+} instead of $Fe(OH)_2$ and $Fe(OH)_3$. some chose the oxidising agents $Al(OH)_4^-$ and $Zn(OH)_4^{2-}$ which would give negative $E^\ominus_{cell}$ values and some used aluminium and zinc to reduce Fe^{3+} to Fe^{2+}.

Question 4

(a) Many candidates could explain that transition elements form complex ions because they have empty d orbitals that were energetically accessible and can accept lone pairs from ligands. Some candidates described this due to having variable oxidation states or partially filled d orbitals.

(b)(i) This question proved challenging to most candidates. Many did not include two Co^{2+} ions in their formula or gave two O_2 molecules or two NH_2^-. The number of ammonia ligands often did not consider the octahedral shape around each Co^{2+} ion.

(ii) Most candidates gave the correct answer.

(iii) Candidates performed well on this question. Those who did not gain full marks referred to light being emitted or answered with an explanation about how colour arises in transition metal complexes rather than explaining why these complexes had different colours.

(c)(i) Candidates found this question difficult. A common error was giving the formula of the complex ion as $(Cd(CN)_4)^{2+}$.

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

(d)(i) This equation was balanced correctly by many candidates.

(ii) Most candidates were able to use their equation in **4(d)(i)** to successfully calculate the concentration of $Na_2C_2O_4$.

Question 5

(a) Most candidates gave the correct bond angles. Common errors included:

- **P** 104° and 120°;
- **Q** 109.5°;
- **R** 45°.

(b) This question was answered well by many candidates.

(c) The majority of candidates identified **Q** and **R** but some included an incorrect third isomer **P**.

(d) Many candidates identified **P** and **R** but some included another isomer **Q**, which was incorrect.

Question 6

(a) This question was answered well. Some candidates thought the catalyst was H^+ and the product, HCl.

(b)(i) The structures were usually drawn correctly. A few candidates used a methyl group rather than the ethyl.

(ii) Most candidates understood that the ethyl group was electron donating and therefore 2, 4-directing.

(c)(i) This question was answered correctly by most candidates. Some omitted the essential condition of heating.

(ii) Most candidates knew that the products for this reaction would be CO_2 and H_2O. Some gave the incorrect formula for 1,2-diethylbenzene as $(C_6H_5)_2(C_2H_5)_2$ or balanced the equation incorrectly.

(iii) Most candidates identified the number of peaks correctly.

(d) (i) Many candidates gave the correct answer. Common errors included that $CDCl_3$ was a reference or removed the OH peak.

(ii) Many candidates identified the compound and completed the table correctly. A common error was to give the groups responsible for the peak at $\delta = 1.2$ as CH_2 and $\delta = 2.6$ as CH_3.

(iii) Most candidates completed the table correctly. Some identified the groups responsible for the peaks but linked them to the incorrect peaks.

(iv) Many candidates knew that the –COOH peak would disappear, but did not explain why.

(e) This question was usually answered correctly. The most common error seen was esterification.

Question 7

(a) The identification of compound **U** proved difficult for many candidates. Common incorrect answers included C_2H_5CN and C_2H_5OH.

(b) The reagents and conditions were usually correct if CH_3CN or C_2H_5CN was identified in **7(a)**. Error carried forward was applied from C_2H_5OH using hot acidified $KMnO_4$.

(c) This question was usually answered correctly.

(d) The equation was well known by most candidates.

(e) Many candidates correctly identified **W** as C_2H_5Br or C_2H_5Cl. A common error was C_2H_5OH.

(f) This question was found to be difficult by many candidates. Even, when ethanol was correctly identified as the solvent, the condition of high pressure was not included.

(g) This question was well answered.

(h) Candidates found this question difficult. Relatively few candidates managed to assign all the reaction types correctly. Candidates were more successful with reaction types 2, 3 and 4 than 1, 5 and 6.

(i) Many candidates gave a correct order: $C_2H_5NHC_2H_5$ – NH_3 – $C_2H_5NHCOCH_3$. Stronger candidates gave good explanations. Weaker candidates found the explanation challenging. Most candidates knew that alkyl groups have a positive inductive effect. Points of note are:

- ○ basicity of these compounds is due to the ability of the lone pair of electrons on the nitrogen atom to accept/form a coordinate bond to a proton
- ○ ‘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.

Question 8

(a) This question was well understood and most candidates could link acidity to weakening the O−H bond. Some did not fully explain that this was due to the delocalisation of the lone pair on oxygen into the benzene ring.

(b) (i) This question proved quite challenging to many candidates. Some correctly named 2,4,6-tribromophenol but then gave as their other product, 2,4-dibromophenol instead of hydrogen bromide.

(ii) This question was usually answered correctly.

(iii) This question was well answered. The most common error was forming H^+ instead of H_2.

(c) Many candidates found this question challenging. Common errors seen were:

  - in step 1 tin and concentrated HCl as the reagents and
  - in step 2 many omitted water as the reagent.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation 51

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

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation 52

Key messages

Candidates should read the information given in the question thoroughly: this applies to both the method and to the subsequent questions.

Anomalous points are points not used in the drawing of a line of best fit. If a point is used in drawing the line of best fit then it should not be considered anomalous even if it does not lie exactly on the line of best fit.

Candidates should round a numerical answer at the end of a multistage question.

General comments

The paper gave candidates the opportunity 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.

Numerical answers should reflect the appropriate number of significant figures. Usually numerical answers should be to three significant figures unless specified on the paper. One significant figure will almost certainly be insufficient.

Comments on specific questions

Question 1

(a) (i) Almost all candidates scored the mark. The question told candidates that a two decimal point balance was used and therefore the correct mass calculated, 13.25 g, need no rounding. A significant number incorrectly rounded to three significant figures and gave 13.3 g.

(ii) The majority of candidates gave excellent answers.

Weaker candidates unnecessarily transferred the sodium carbonate from the small beaker to a larger beaker prior to dissolving in step 1.

The most common error in responses was omission of rinsing the 50 cm^3 beaker after transfer of aqueous sodium carbonate formed in step 1 to the volumetric flask.

Other common errors included:

- assuming the solid sodium carbonate was aqueous to start with
- transferring solid sodium carbonate directly into the volumetric flask
- transferring the aqueous sodium carbonate 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.

(b) (i) Most candidates realised that solution **Y** had to be used for rinsing as it was the solution that would be used in the pipette. Some used distilled water before solution **Y** which was acceptable. Distilled water alone was incorrect.

A significant number of candidates chose to write 'distilled water or solution **Y**'. This is a case of two answers being given, one of which is incorrect, so no credit was given.

Many candidates opted to explain why the pipette needed rinsing rather than what it should be rinsed with.

(ii) Almost all candidates knew that detection of the end-point involved a colour change.

(iii) Candidates gave a variety of acceptable answers.

Many non-scoring responses suggested even/gentle/constant heating or the idea of a flammable substance being involved.

Some candidates had not understood the method described in the stem of the question and consequently named the solid incorrectly as Na_2CO_3.

(iv) Most candidates seemed familiar with the idea of achieving constant mass to confirm all water had been evaporated but some omitted the necessary heating aspect

Common errors included:

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

(c) (i) Many candidates were unable to give the correct burette readings.

Most candidates determined the correct volume of solution **X** by subtraction of the burette readings, but many failed to include the second decimal place.

(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 (ie ± 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.

(d) This question differentiated well. Many candidates scored all three marks.

Some candidates were confused by the fact that they were starting with the mass of NaC*l* and ending up with the concentration of Na_2CO_3.

Almost all candidates were able to successfully calculate that the mass of residue was 1.17g.

Weaker candidates failed to divide this by the M_r of NaC*l* (58.5). Instead, twice 58.5 (117) was chosen, presumably to match the stoichiometry coefficient given in the equation. Others assumed the residue was Na_2CO_3 and used this M_r (106) then doubled the answer to match the stoichiometry of the equation.

The concentration of **X** was found by understanding *n*(NaC*l*) = *n*(HC*l*). Some candidates did not read the question and chose 13.50 cm^3 as the volume of HC*l*, rather than 0.01335dm^3, when calculating *c*(HC*l*).

The concentration of **Y** was found by understanding *n*(Na_2CO_3) was half that of *n*(NaC*l*) and the volume of **Y** was 25.0 cm^3. Weaker candidates incorrectly assumed a 1 : 1 ratio of *n*(Na_2CO_3) : *n*(NaCl)

(e) This question was answered well with most candidates understanding that the mass of NaC*l* would be too high because of the remaining water, leading to the perceived concentration of solution **Y** (Na_2CO_3) being too high.

Weaker candidates thought that the remaining water would dilute the solution.

Question 2

(a) (i) The pipe-clay triangle is not a well-known piece of apparatus. Near misses such as 'pipe triangle' or 'clay triangle' were allowed for this series.

(ii) Most candidates knew that a fume hood was used because one of the products (SO_2) was gaseous and toxic (poisonous was an equally acceptable term).

Incorrect responses referred to flammability, prevention of heat loss or draft-exclusion or used a general term to describe the gas, such as harmful.

(iii) Most candidates knew sulfur was in excess to ensure that all metal **M** reacted. Some candidates picked up on the use of *powdered* sulfur and gave answers based upon rate of reaction which was not credited as the rate of reaction was irrelevant in the case.

Incomplete answers included 'to cover the metal wire'. The most common incorrect answer was 'to reduce percentage error'.

(b) Almost all candidates completed the table correctly.

(c) Although most candidates recognised the mass of metal **M** as the independent variable several missed the mark by stating 'metal **M**' without reference to its mass or 'mass' without reference to metal **M**.

(d) (i) There were only 5 points to plot and most were on intersections of gridlines. Several candidates plotted one or more of these points incorrectly, with the point at (1.14, 0.28) frequently plotted at (1.04, 0.28) or (1.4, 0.28).

Not all candidates scored the mark for drawing a correct line of best fit from the origin to split the first four points so two were above and two below the line and completely ignoring the last point which was anomalous. A common error was to draw a 'first to last' type of line from the origin and through the fourth point.

Many candidates ignored the instruction to 'draw a **straight** line of best fit which includes the **origin**'. A significant number of candidates attempted to draw a curve and many other candidates drew otherwise good lines of best fit except these lines did not go through the origin.

(ii) Almost all candidates could identify the anomalous point, but very few could explain what had caused the anomaly. If, as was expected, the anomaly was above the line, it was likely to be caused by unreacted sulfur remaining in the crucible. If it was below the line, then the likely cause was that the metal had not fully reacted.

(e) This calculation was attempted well by most candidates. A minority did not cover a sufficient range (at least 0.8 units on the x-axis) or misread the co-ordinates of their selected points on the line. A significant number ignored the requirement to give the answer to three significant figures.

(f) As there was (at least) one anomalous point, the results should be regarded as unreliable.

Many candidates stated the results were reliable. The following incorrect explanations were seen:

- there was only one anomalous point
- most points were on or near the line of best fit
- line of best fit goes through the origin.

Other candidates correctly stated the results were unreliable but gave the following incorrect reasons:

- there were many anomalous points (there were not 'many')

- most points were not on the line of best fit (some candidates wrongly stated that any point not on the line of best fit was anomalous despite the fact these points were used in drawing the line of best fit).

(g) (i) Only a minority of candidates could complete this difficult calculation. Many candidates attempted to use the data from **2(b)** or their graph in **2(d)(i)**.

(ii) Most candidates failed to appreciate they were required to compare their gradient calculated in **2(g)(i)** to their gradient calculated in **2(e)** but candidates who answered in terms of a comparison of the two gradients were awarded this mark.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation 53

Key messages

Two areas worthy of close attention are as follows:

Understanding experimental design: Why are certain steps or reagents used in the experiment? For example, why choose a specific indicator in a titration, or use specific reagents in synthesis?

Exploring alternatives: Are there other ways to achieve the same result? For instance, could a potentiometric or thermometric titration work as well as an acid-base titration? Considering and analysing possible alternatives enhances understanding.

General comments

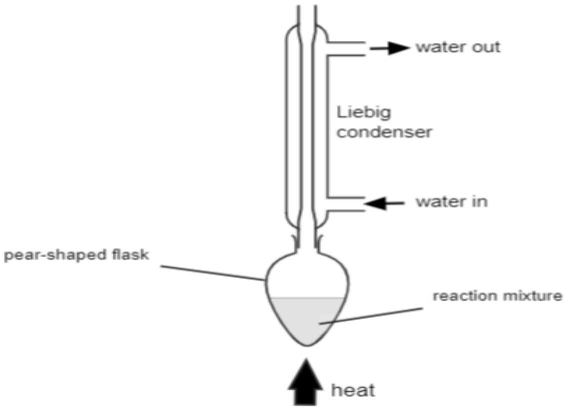
A strong foundation in practical chemistry is vital at this level. Practise in performing a wide variety of experiments and improving data analysis skills should ensure candidates are confident when tackling this examination.

Comments on specific questions

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

(b) Weighing by difference is preferred over other weighing techniques because it minimizes errors caused by solid residue remaining in the weighing boat after transfer. This is a standard laboratory procedure that candidates should be familiar with. The results tables presented were generally appropriate for the weighing method described. It is crucial to ensure that table headings are clear and unambiguous, and that they include the correct units.

(c) Many candidates were unfamiliar with the experimental setup required to carry out a reflux technique successfully.



Whilst some leeway is given in the accuracy of drawing diagrams, the use of normal conventions for their construction and labelling is very much encouraged. Diagrams are easier to draw in a way that makes it easier to see how the apparatus is joined together.

(d) (i) Many candidates correctly recognised why the measuring cylinder was appropriate. Some suggested that its use would result in a lower percentage error. A significant number of others expressed concerns that pipettes with a sufficient capacity might not be available, or that the measuring cylinder would allow the volume to be measured in a single operation.

(ii) Most candidates correctly identified the need for completion of the reaction to produce the maximum mass of precipitate in this quantitative procedure. The most common incorrect response was 'to allow time for the precipitate to settle'. The suggestion that waiting ensures all the aqueous alkaline iodine has fully reacted is incorrect, as iodine is added in excess.

(iii) Washing the residue C with a small volume of cold distilled water is done to remove any unwanted water-soluble substances from the precipitate, with excess aqueous alkaline iodine being the most likely. This step is not intended to prevent further reaction, as suggested by some candidates.

(iv) Cold solvent, rather than hot, is used to minimize the amount of solid C that dissolves during the washing process. Increasing the temperature of the water is unlikely to induce a chemical reaction.

(e) (i) Almost all candidates carried out this calculation correctly.

(ii) The most common error made in this part of the calculation was neglecting the stoichiometry of the reaction. Many candidates failed to multiply the amount of $(C_6H_2I_2O)_2$ produced by two in order to calculate the amount of $C_9H_8O_4$ in the original powdered tablets.

(iii) Candidates were able to perform this calculation effectively. A few used 0.4g instead of 0.409g for the mass of powdered tablets added to the pear-shaped flask in step 2.

(f) Ensuring that the collected precipitate is completely dry can be challenging. If any water from the reactants remains, the apparent mass of the solid will be higher than the actual mass of the substance produced. As a result, the calculated percentage by mass of aspirin will be higher than the true value, in this case.

Question 2

(a) The wavelength chosen for colorimetric analysis corresponds to the point of maximum absorption for the coloured solution, which is the peak on the graph in Fig. 2.1, at approximately 587 nm. Credit was awarded for suggesting a wavelength in the range of 580 to 595 nm.

(b) (i) Few candidates answered this question incorrectly.

(ii) Those candidates who did not achieve full marks often missed the step of mixing the final solution thoroughly.

(c)(i) Most candidates correctly suggested the appropriate volumes required to make mixtures of the correct concentration of crystal violet.

(ii) The dependent variable, absorbance, was correctly identified by most candidates.

(d)(i) Most candidates correctly plotted points on the grid and drew a suitable line of best fit. The centre of the point marker (x) should coincide with the x and y coordinates for all points.

(ii) Almost all candidates identified the most anomalous point correctly. Fewer candidates were able to provide a suitable explanation for why the point deviated from the line of best fit. According to the best fit line, a solution with a concentration of 1×10^{-4} mol/dm^3 should have an absorbance of 0.358. The anomaly therefore corresponds to a solution of lower absorbance, and, consequently, concentration. A correct explanation would involve identifying why the solution ended up a concentration that was too low: either because too much water or too little solution E was used in preparing that diluted solution.

(iii) The graph provided clear evidence to support the conclusion that absorbance is directly proportional to the concentration of ($C_{25}H_{30}N_3Cl$(aq)). A positive linear relationship, however, does not quite convey the same meaning.

(iv) The simplest way to improve the reliability of the results is to identify any anomalies and then repeat that reading. Gaining more data, to identify and eliminate anomalies, is crucial to improving the reliability of data.

(e)(i) The simple explanation for this question is that the solutions are mixed at $t = 0$ and **then** placed in the colorimeter. At $t = 0$, the sample is not yet in the colorimeter, so no measurement can be made. Careful analysis of the question helps candidates provide a suitable response to this type of question.

(ii) Many candidates correctly recorded the required coordinates and calculated the half-life from them. A significant number did not follow the instruction to measure the half-life starting at 100 seconds.

(iii) Most candidates recognised that the two half-life values were very similar. When experimental error is considered, there is no significant difference between them, leading to the conclusion that the reaction is first order.