CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Questions 2, **4**, **21** and **29** were found to be easier.

Questions 13, **14**, **22**, **35** and **36** were found to be particularly difficult. These questions will be looked at in greater detail.

Comments on specific questions

Question 13

The most common chosen incorrect answer was option **B**. This question involves the selection and use of data. After reaching constant pressure, it can be deduced that the system has a volume of $2.00\,\text{m}^3$, the number of moles of methane present is 7.0, and the temperature is 800 K. Since $PV = nRT$ the pressure in the system is $(7.0 \times 8.31 \times 800) \div 2.00$. This gives the answer 23.268 kPa.

Question 14

The most commonly chosen incorrect answer was option **A**. Candidates may have confused the difference between a 3p orbital, which holds a maximum of two electrons, and the 3p subshell, which holds a maximum of six electrons. In an isolated phosphorus atom, each of the 3p orbitals holds a single unpaired electron, hence the correct answer is option **D**.

Question 22

The most commonly chosen incorrect answer was option **B**. This suggests candidates understood that magnesium atoms each donate two electrons to the ‘sea’ of delocalised electrons and that sodium atoms each donate one, making statement 2 true. Candidates did not recognise that sodium has a giant metallic structure and a lower melting point than sulfur, which has a simple molecular structure. This makes statement 1 not true. Candidates also did not recognise statement 3 is true. Phosphorus and sulfur do not conduct electricity because they have simple molecular structures.

Question 35

The most commonly chosen incorrect answer was option **B**, suggesting both percentage yield and relative rate of reaction were poorly understood. The amount of 2-bromo-2-methyl butane present at the start is $30.18 \div 150.9 = 0.200$ moles. The product X is 2-methylbutan-2-ol which has an M_r of 88. The amount of 2-methylbutan-2-ol formed is $12.32 \div 88 = 0.14$ moles. $0.14 \div 0.200$ is 0.700, this means the percentage yield of X is 70%. Reaction 1 is faster than reaction 2 because the C–Br bond is longer and therefore weaker than the C–Cl bond. Option **C** matches both these conclusions.

Question 36

The most commonly chosen incorrect answer was option **C**. This states that alkene P is methylpropene, $(CH_3)_2C{=}CH_2$. If this is treated with hot concentrated acidified $KMnO_4(aq)$, the carbon-containing products are propanone and carbon dioxide. Option **A**, that alkene P is 2,5-dimethylhex-3-ene $(CH_3)_2CHCH{=}CHCH(CH_3)_2$, is the correct answer. If this is treated with hot concentrated acidified $KMnO_4(aq)$, the only carbon-containing product is methylpropanoic acid.

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Paper 9701/12
Multiple Choice

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

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

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

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

General comments

Candidates found **Questions 2**, **3**, **5**, **7**, **8**, **12**, **13**, **14**, **15**, **20**, **21**, **24** and **27** easier.

Questions 6, **9, 18**, **37** and **38** were found to be particularly difficult, these will now be looked at in greater detail.

Comments on specific questions

Question 6

The three incorrect options were all commonly chosen for this question. One mole of methanol is formed from one mole of carbon, two moles of hydrogen and half a mole of oxygen. The total enthalpy change of combustion of these amounts of these elements is –394 + (2x – 286) = –966. As –966 – (–726) is –240, the answer is option **A**.

Question 9

The most commonly chosen incorrect answer was option **B**. This question required great care in more than one area, including the handling of units. 120 cm^3 of oxygen, measured at room conditions, is 5.00×10^{-3} moles. From the equation, $2H_2O_2 \rightarrow 2H_2O + O_2$, it can be deduced that 1.00×10^{-2} moles of hydrogen peroxide have decomposed in 120 seconds to produce this amount of oxygen. The change in concentration of hydrogen peroxide was therefore 0.20 mol dm^{-3}, since the volume of the solution was 50 cm^3. The average rate of the reaction is $0.20 \div 120 = 0.0017$ mol dm^{-3} s^{-1}.

Question 18

The most commonly chosen incorrect answer was option **C**. This suggests many candidates understood that compound M is hydrolysed by water to produce HCl which turns the moist litmus paper from blue to red. Of the two options, aluminium chloride or phosphorous pentachloride, which would give this reaction only aluminium chloride reacts with water to form a solution that gives a white precipitate with NaOH(aq) which is soluble in excess. The correct answer is option **A**.

Question 37

The most commonly chosen incorrect answer was option **A**. S has molecular formula C_4H_{10} so it can only be butane or methylpropane. If S is butane, the two monochloroalkanes produced are 1-chlorobutane and 2-chlorobutane. Since 2-chlorobutane reacts with hot ethanolic KOH to form two alkenes, but-1-ene and but-2-ene, S cannot be butane. S is therefore methylpropane. The two monochloroalkanes are 1-chloromethylpropane and 2-chloromethylpropane. Alkene T is therefore methylpropene. This reacts with hot concentrated acidified $KMnO_4$ to produce carbon dioxide and propanone, option **B**.

Question 38

The most commonly chosen incorrect answer was option **A**. $C_2H_2Br_2$ has a C=C bond. The isomers of $C_2H_2Br_2$ are therefore 1,1-dibromoethene, cis-1,2-dibromoethene and trans-1,2-dibromoethene. The correct answer is option **B**.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

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

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

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

General comments

Candidates found **Questions 2**, **4**, **6**, **7**, **9**, **10**, **31**, **33**, **36**, **37** and **38** easier.

Questions 15, **18**, **20**, **26**, **29**, **32** and **40** were found to be more difficult. These questions will now be looked at in greater detail.

Comments on specific questions

Question 15

The most commonly chosen incorrect answer was option **B**. 7.15 cm^3 of 0.100 mol dm^{-3} H_2SO_4 contains 7.15×10^{-4} moles. The sulfuric acid reacts with twice as many moles of sodium hydrogencarbonate $H_2SO_4 + 2NaHCO_3 \rightarrow Na_2SO_4 + 2CO_2 + 2H_2O$. Candidates whose chose option **B** may have missed the multiplication of the calculated number of moles H2SO4 to give the moles of $NaHCO_3$. 7.15×10^{-4} moles $\times 2 = 1.43 \times 10^{-3}$ moles of $NaHCO_3$ which has a mass of 0.120 g. The washing powder therefore contains 12% of $NaHCO_3$ by mass.

Question 18

The most commonly chosen incorrect answer was option **C**. Option **C** is incorrect as magnesium hydroxide does not react with steam. Option **A** is incorrect, no hydrogen is produced. Option **B** is incorrect, calcium oxide does react with water, producing calcium hydroxide. Option **D** is correct, the equation is $SrO + H_2O \rightarrow Sr(OH)_2$.

Question 20

The most commonly chosen incorrect answers were options **A** and **C**. This suggests many candidates knew that the structure and bonding of Period 3 oxides changes from giant ionic to giant covalent to simple molecular. Statement 2 is incorrect – aluminium oxide does not dissolve in water, silicon dioxide is not hydrolysed by water. Statement 1 is also incorrect – the highest oxidation state is shown by sulfur, in SO_3.

Question 26

The most commonly chosen incorrect answer was option **C**. The hydrolysis of ethanenitrile by NaOH(aq) produces sodium ethanoate, $CH_3COO^-Na^+$. Since the reaction has an 80% yield, 0.160 moles of $CH_3COO^-Na^+$ are produced. This has a mass of 13.1 g.

Question 29

The most commonly chosen incorrect answer was option **D**. Candidates may not have understood that this is an addition rather than substitution reaction. Ethanal reacts with KCN through a nucleophilic addition mechanism, forming the intermediate $CH_3CH(CN)O^-$. This can gain a proton from HCN to form the product, $CH_3CH(CN)OH$.

Question 32

The most commonly chosen incorrect answer was option **B**. The substances which fit the formula and give a positive iodoform test are pentan-2-ol and 3-methylbutan-2-ol. Both of these alcohols exist as a pair of optical isomers, giving a total of four alcohols.

Question 40

The most commonly chosen incorrect answers were options **B** and **C**. The abundance data for the M peak and the M+1 peak means that there are two carbon atoms per molecule, since $(100 \times 2.2) \div (1.1 \times 100) = 2$. This leaves options **A** and **C** as possible answers. It cannot be CH_3COOH as this would cause a fragment peak at *m/e* = 17 due to the –OH group. The fragment peak at *m/e* = 31 due to the $–OCH_3$ group, confirms the compound is option **A**.

CHEMISTRY

Paper 9701/14
Multiple Choice

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

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

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

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

General comments

Questions 1, **2**, **6**, **7**, **9**, **11**, **17**, **18**, **23**, **27**, **31**, **33**, **35** and **40** were found to be easier.

Candidates found **Questions 8**, **10**, **21**, **36** and **37** more difficult, these questions will now be looked at in greater detail.

Comments on specific questions

Question 8

The most commonly chosen incorrect answer was option **D**. This suggests candidates understood that the shape of the Boltzmann distribution is dependent on temperature, so the answer cannot be options **A** or **C**. Many candidates did not understand the effect of increasing or decreasing the temperature. An increase in temperature flattens the distribution, while a decrease in temperature increases the height of the peak, so the answer is option **B**.

Question 10

The most commonly chosen incorrect answer was option **C**. 69.0 g of NO_2 is 1.50 moles. To cause an increase in pressure of 10%, the number of gas molecules must increase by 10%. This means the amount of gas molecules must increase by 0.150 moles. The equation for the decomposition of NO_2 is $2NO_2 \rightarrow N_2 + 2O_2$. When 0.300 moles of NO_2 decomposes, 0.150 moles of N_2 and 0.300 moles of O_2 are produced, causing the total amount of gas molecules to increase by 0.150 moles. 0.300 moles of O_2 molecules have a mass of 9.60 g, so the answer is option **B**.

Question 21

The most commonly chosen incorrect answer was option **B**. The observations show that element X can only be aluminium. Element Y can be sodium or magnesium. Of the options given, Element Z can only be phosphorus. The only option consistent with all these conclusions is option **A**.

Question 36

The most commonly chosen incorrect answer was option **C**. This question may be considered by looking at the alcohols with formula C_4H_9OH that could react with methanoic acid. Butan-1-ol produces one ester. Butan-2-ol produces two esters, since the ester has a chiral carbon atom. 2-methylpropan-1-ol and 2-methylpropan-2-ol each produce one ester. This gives a total of five possible esters of methanoic acid with the formula $C_5H_{10}O_2$. Candidates who chose option **C** may not have considered the chiral carbon of Butan-2-ol

Question 37

The most commonly chosen incorrect answer was option **A**. 120 cm^3 of 0.50 mol dm^{-3} sodium carbonate contains 0.060 moles. This reacts with 0.120 moles of –COOH groups, since the ionic equation for the reaction is $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$. It is possible that candidates who chose option **A** missed out this step. Each citric acid molecule contains three –COOH groups. Therefore, there are 0.040 moles of citric acid present.

CHEMISTRY

Paper 9701/21
AS Level Structured Questions

Key messages

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

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

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

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

General comments

Candidates should have a secure understanding of the term ‘observation’ and how to answer questions that ask for observations. This might include:

- a solid dissolving or disappearing when a reaction has ended
- effervescence when a gas has evolved or cessation of effervescence when a reaction has ended.

Candidates who performed better had a good level of recall and understanding of previously taught concepts such as definitions of isotopes/simple formula/balanced equations/conduction of metals and ionic compounds.

Candidates had sufficient time for all questions to be answered.

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

Candidates are expected to balance all chemical equations.

Comments on specific questions

Question 1

(a) (i) Most candidates answered this correctly. Some referred incorrectly to covalent bonding or, less commonly, to various types of intermolecular force. The use of the term electrovalent was used by some candidates. Candidates should be encouraged to use the syllabus term 'ionic'.

(ii) Many candidates either referred to delocalised electrons without any word suggesting movement, or to the movement of free electrons without the idea that the electrons are delocalised, so did not gain credit. Other terms such as 'free' or just 'moving/mobile electron' were commonly used but what was 'moving' or 'free' was not clear. Charge moving/being carried or conducting were common misconceptions.

(iii) Some candidates recognised conductivity involved particle movement. Candidates who performed less well referred to conductivity based on movement of electrons or negative ions only, rather than the movement of both positive and negative ions. A significant number of candidates described the non-movement (of ions) in solids, which was not asked for.

(b) (i) Candidates performed well on this question, although a number thought the product of the reaction was sodium oxide.

(ii) The formula of sodium oxide, Na_2O, was not well known. In equations where correct formulae were shown, a significant proportion were not balanced.

(iii) The most common incorrect answers referred to reactions that occurred that are not observable, e.g. hydrogen being produced or sodium hydroxide being produced. A small number of candidates mentioned temperature change despite the question instructing them not to refer to temperature change. Many candidates incorrectly referred to vigorous/non-vigorous reactions. A small number of candidates contradicted themselves, e.g. both produce bubbling, but then saying only one reaction produced effervescence. Candidates should be reminded to record observations, rather than draw conclusions, e.g. many candidates stated a gas is formed / no gas is formed, which is a conclusion not an observation.

(c) Most candidates were able to calculate the oxidation numbers correctly. Some misinterpreted the question and calculated the oxidation number of chlorine rather than sodium and phosphorus. Many candidates said oxidation numbers were based on number of valence electrons without specifying how many. Only the candidates who performed well were able to relate oxidation number to the number of electrons in the outer shell.

(d) Overall, this question was well answered with candidates using the data provided to show that the hypothesis was incorrect. The data was well processed. Some candidates made an error with an oxidation number or did not give a comparative answer. The oxidation number of hydrogen was the most common incorrect answer (given as $+2$). Other candidates did not address the question and described other factors such as bonding, structure or intermolecular forces of attraction.

Question 2

(a) The essential word 'atoms' was often omitted when recalling the definition of the term isotope. The incorrect use of the terms compounds/molecules/elements were commonly seen. A small number of candidates incorrectly wrote about differences between isomers or relative atomic mass.

(b) (i) This question was one of the most accessible questions on the paper with the majority of candidates gaining full credit for the calculation of the relative atomic mass of iron.
A small number of candidates did not use all three isotopes or gave the answer to the incorrect number of decimal places, thus not gaining full credit.

(ii) The common error in this question was giving the number of neutrons instead of nucleons. 30 nucleons was commonly seen. A small number of candidates gave the relative atomic mass instead of the number of nucleons.

(c) This was found to be one of the most challenging questions for the candidates with a wide range of answers. Candidates who were able to deduce that there were five pairs of electrons in the shell with principal number $n = 3$ performed well. Most candidates had a lack of understanding of Aufbau principle for filling orbitals.

(d) Inclusion of state symbols for ionisation energy equations are essential. A significant number of candidates did not include state symbols. A small number used (s) for the initial state of Fe rather than (g). Some equations showed addition of an electron, other equations were incorrectly balanced.

(e) This question required candidates to have a good understanding of ionisation energy rather than just repeating the rote learning explanation of ionisation energy across Period 3. Some candidates listed the relevant factors affecting ionisation energy but then did not apply them to the two isotopes. Only the candidates who performed well were able to gain full credit by being able to apply the factors affecting ionisation energy to the isotopes of iron. The most common error was referring only to 'nuclear attraction' without mentioning attraction to the 'outer' electrons. Many candidates incorrectly thought that having more nucleons would have an impact on atomic radius. A smaller number also incorrectly thought that additional neutrons would affect the nuclear charge.

Question 3

(a) (i) Overall, the Maxwell Boltzmann distributions were poorly drawn. Nearly all candidates began at the origin, but many candidates incorrectly had the peak at the same height as the original or to the left of the original curve. Most candidates seemed to cross the original curve at the end or allow the curve to join with the original curve. Candidates who performed well in this question drew a new curve with a lower peak and to the right of the original and whose tail was higher than the original curve.

(ii) Answers describing just one of the factors were common. Many candidates did not refer to activation energy at all and those that did, did not appreciate that it is a greater proportion of molecules that have energy greater or equal to the activation energy. Often candidates omitted either the idea of 'frequency' or 'successfulness' from their description of collisions. Some incorrectly thought that changing the temperature would change the activation energy. It should be noted that 'successive' does not mean the same as 'successful'.

(iii) The majority of candidates could identify the role of nickel as a catalyst.

(iv) The majority of candidates were able to label the Maxwell Boltzmann curve with a lower activation energy, although some also drew a second Maxwell Boltzmann curve.

(b) Candidates who could recall the syllabus definition of 'Le Chatelier' gained full credit. Common errors were to define dynamic equilibrium or to describe catalysis and reaction rate or to define Hess' Law. Misconceptions shown by the candidates are that the system or reaction shifts rather than the position of equilibrium and that the shift in equilibrium position completely negates the effect of a change in conditions.

(c) Candidates who performed less well could access this question through discussing the effect of temperature/pressure on yield rather than discussing energy change/gas moles. Overall, this question was generally well answered although same candidates did not recognise that 300 K or 350 K are temperatures not pressures. Some candidates incorrectly described the effect of temperature on pressure and did not refer to a conclusion, whilst some candidates just stated a value from the curve e.g., at 300 K and 100 atmospheres, the yield was 'x%'. Several were confused about direction of equilibrium shift and moles, and a correct answer was contradicted.

Question 4

(a) This was well answered. A few candidates miscounted the number of atoms; some gave the molecular formula instead of the empirical formula. A small number attempted to write a structural formula for the cyclic compound.

(b) (i) The majority of candidates gained full credit for the calculation of the amount, in mol, of I_2. A small number made a 10× error when (unnecessarily) changing standard form to longhand.
Only a very small number of candidates incorrectly gave the answer to 2 significant figures or made an error in cm^3 to dm^3 conversion.

(ii) Many candidates gained 1 mark here; far fewer were awarded full credit. The most common incorrect answer involved multiplying the number of moles in **(4)(b)(i)** by 176 but omitting the factor of 40. Of those who did multiply by both 176 and 40, a number of candidates struggled with rounding, converted 0.0997 to 0.01. Other less common errors involved scaling using the volume of $155\,cm^3$, calculating an incorrect M_r (despite being given the M_r of 176 in the question) or attempting to apply a 1 : 2 mole ratio.

(iii) Almost all candidates could identify the role of $I_2(aq)$ as the oxidising agent.

(iv) Only the better performing candidates achieved full credit on this question. References to sigma and pi bonds were not seen although C=C bond breaking was common. No credit was given to the breaking of the double bond without specifying which double bond was broken. Many candidates did not recall acidified manganate as a powerful oxidising agent, with many answers not identifying the parts of the molecule that would react or suggesting products without reference to the parts of the molecule which reacted e.g., carboxylic acids would form. Some answers incorrectly described the end point of a titration or financial costs.

(c) Candidates gained full credit by using all the data required including the table and structures provided. Many partially correct answers were seen, but far fewer answers gave all three required pieces of information. OH was often written without showing the bond. It should be noted that for infrared spectra absorptions, a wavenumber, a bond and a functional group are three key pieces of information and all are required.

Question 5

(a) Even the candidates who performed well overall found this question challenging. A significant number of candidates drew a monoester, which gained partial credit, rather than a di-ester. Some answers incorrectly showed oxygen with 3, 4 or 5 bonds or carbon with 3, 5 or 6 bonds. Candidates should count the number of bonds made by H, C and O in their structures carefully.

(b) This accessible question meant that the majority of candidates could recognise that the type of reaction occurring with compound **A** was hydrolysis.

(c) (i) Full credit was awarded to candidates for identifying the products of the reaction as the sodium salt, carbon dioxide and water. Many candidates incorrectly reacted only one of the carboxyl groups or omitted CO_2 and H_2O. A few candidates gave H_2CO_3, which did not gain any credit. Some tried to balance the equation using H_2 and O_2 or gave a $–CO^- Na^+$ rather than $–COO^-Na^+$ product.

(ii) Even better performing candidates overall found this question challenging. Many candidates incorrectly stated that alcohols do not react with carbonates, or that compound **C** does not contain a carboxylic acid group. Other candidates stated that compound **C** is not an acid without making any comparison to compound **B** or incorrectly stated that alcohols are bases. Some candidates correctly explained that alcohols are weaker acids than carboxylic acids in terms of the inductive effect destabilising the conjugate base relative to a carboxylate salt.

(d) (i) Many partially correct answers were seen for this question. Relatively few candidates stated all three required pieces of information for the reagents and conditions. Some candidates used capitalisation in the formulae for potassium manganate(VII), and some candidates used Kr instead of K in the formula for potassium dichromate. Omission of (aq) for NaOH and reflux for manganate/dichromate were the most common errors.

(ii) The majority of candidates could recognise that propane-1,3-diol underwent oxidation to form propanedioic acid.

(e) (i) $NaBH_4$ was a common error, but this was otherwise well answered.

(ii) Candidates found this question challenging and even those who got the correct product often struggled to balance the equation correctly with water and 8[H]. $HOCCH_2COH$ was the most common incorrect answer.

(iii) The candidates found this a difficult question. It was common for candidates to incorrectly name the diol and not the product after the reaction with excess PCl_5. Some attempted a structure rather than a name and some gave near-misses of 1,2-dichloropropane or 1,4-dichloropropane. A handful of candidates confused the prefix of prop- for pent-.

Question 6

(a) The majority of candidates could recognise that **F**, **G** and **H** were carbonyl compounds. A few incorrectly stated the functional group was carboxyl.

(b) The test for a carbonyl group was well known. The majority of candidates could correctly identify 2,4-DNPH as the reagent used to test for a carbonyl group with an orange precipitate being produced. A small number of candidates jumbled up the letters or the numbers in 2,4-DNPH.

(c) (i) This was generally well answered. Some candidates made up their own compounds and some stated the homologous series name only rather than using the information given to them in the question.

(ii) Most candidates recognised that this was the iodoform reaction. A common error was CH_3I for iodoform rather than CHI_3.

(iii) The majority of candidates recognised that the alcohol must contain $CH_3CH(OH)$ and stated the correct formula for ethanol or another secondary alcohol. While generally well answered, common errors included drawing propan-1-ol or carboxylic acids.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions

Key messages

- Reproduction of accurate detail in definitions is key to candidates demonstrating their full knowledge of the subject.

- Candidates who performed well engaged with the details given in the question and produced considered responses using relevant knowledge accurately. Candidates who performed less well produced more general answers which were not necessarily specific to the question or were imprecise.

General comments

Some candidates did not engage with information from a table or a figure when specifically asked to use them in an explanation.

Improper use of vocabulary specific to the syllabus can create ambiguity in responses. For example, the use of the term ‘similar’ as equivalent to ‘same’ when there is a comparison of shielding or nuclear charge in different species.

Comments on specific questions

Question 1

(a) (i) Many answers used the appropriate syllabus term ‘giant molecular’. Weaker responses referred only to ‘giant’. Incorrect identification of the lattice structure as ‘giant metallic’ or ‘giant ionic’ was also seen.

(ii) Appropriate explanations, in terms of the movement of delocalised electrons, were seen in a minority of answers. Weaker responses identified that ‘graphite contains delocalised electrons’ without explanation in terms of ‘movement’ of these electrons. Many responses did not indicate that the electrons involved in the conduction process were delocalised.

(iii) Some excellent answers explained that diamond is unable to conduct electricity because ‘all the valence electrons in each carbon atom are involved in covalent bonding’. Weaker responses stated that there are no delocalised electrons.

(b) (i) The chemical equations which represent the reactions of phosphorus(V) chloride and silicon(IV) chloride were generally well known. Not all equations which showed appropriate reactants and products were balanced. Some equations did not start with the appropriate formula for the reactant, while others showed incorrect formula for phosphorus or for silicon containing products. Equations which produced $POCl_3$ rather than H_3PO_4 were seen even though the question specifically referred to the addition of an excess of water to phosphorus(V) chloride.

(ii) The appearances of both phosphorus(V) chloride and silicon(IV) chloride were not well known. Few candidates correctly described the states of both of these compounds at room temperature.

(iii) The appearance of the mixtures after separate samples of phosphorus(V) chloride and silicon(IV) chloride were added to water were rarely described. It was more common for answers to describe the production of misty fumes during the reaction.

(c) (i) Good understanding of the term amphoteric was demonstrated by the majority of candidates.

(ii) Answers which stated the correct formula were common. Occasionally, the name of the oxide was given rather than the formula.

(d) (i) Identification of the forces of attraction broken during melting for the different compounds were generally well known. Errors included the breaking of permanent dipoles in ionic compounds and the breaking of intermolecular forces and covalent bonds in giant covalent compounds.

(ii) This question proved to be challenging. Candidates were required to evaluate the hypotheses based on the information in Table 1.1. Many answers were vague and did not relate directly to the process of breaking forces of attraction during melting to relevant examples in the Table 1.1.

Some candidates gave explanations in terms of sodium oxide and magnesium oxide when the hypothesis was based on non-metal oxides.

Question 2

(a) (i) Well-rehearsed answers were given in a significant proportion of responses. Excellent knowledge was demonstrated by those that gave a complete definition in relation to the unified atomic mass unit and then went on to define the unified atomic mass unit. Weaker responses defined relative isotopic mass rather than relative atomic mass or omitted key details in the comparison ‘to one twelfth of the mass of a carbon-12 isotope’.

(ii) Many candidates correctly deduced the relative abundance of the unknown isotope and used this value appropriately to calculate its relative isotopic abundance. Weaker responses did not attempt to find the abundance of the unknown isotope.

(b) This question proved to be demanding. Candidates were required to apply knowledge of the electronic configuration of an iron atom to that of an iron(II) ion and to show an understanding that within a sub-shell electrons are unpaired, in each of the orbitals, before pairing occurs. ‘Zero’, ‘three’ and ‘six’ were common incorrect answers.

(c) The majority of candidates represented the shape of an s orbital correctly. Occasionally, diagrams represented the number of electrons within each energy level. The shape of hybrid orbitals and p orbitals was also seen.

(d) This question was well answered.

(e) The majority correctly deduced that there would be a decrease in the radius. A relatively small proportion described the change in size due to the loss of a shell of electrons even though this is the most significant factor. It was more common for answers to describe the overall change in nuclear attraction due to loss of electrons. Incorrect references to ‘increase in nuclear charge’ or ‘same shielding’ were seen.

Question 3

(a) (i) In order to remove ambiguity when defining an addition reaction candidates need to refer to ‘a reaction where two or more reactants produce only one product’. Examples of types of addition reactions are irrelevant.

(ii) Some accurate diagrams representing this electrophilic addition reaction were seen. Poorer diagrams did not clearly show the start of a curly arrow from a specific bond or lone pair. Incorrect details of the mechanism included dipoles on C=C, incorrect dipoles on H–Br or with an intermediate with no positive charge.

(iii) It was relatively common for candidates to give explanations in terms of the formation of the more stable intermediate or carbocation. Less precise answers created ambiguity by describing '2-bromopropane as the carbocation or intermediate'. Many candidates appreciated that the answer was due to the 'inductive effect'. Only the best answers linked 'a greater inductive effect due to the presence of more alkyl groups on the C^+ of the intermediate'.

(b) (i) A significant proportion of candidates identified hydrogen as the limiting reagent. Some excellent responses then used Fig. 3.2 to explain their reasoning in terms of the amount of X remaining when the reaction was over. Weaker responses did not refer to Fig. 3.2. Some incorrectly identified nickel as the limiting reagent.

(ii) Many responses did not engage fully with the question and the link between the decrease in gradient and the decrease in rate of reaction was relatively uncommon.

(c) This calculation proved to be challenging. Many answers used the correct idea that the overall enthalpy change was the difference between energy needed to break bonds minus energy released when bonds are made. Of those, a significant proportion were unable to determine the actual number and type of bond made and broken. It was more common for answers to show the correct energy involved when bonds were made. A common mistake involved no consideration of the energy required to break the H–H bond or broke the wrong number of H–H bonds in the reaction.

(d) (i) Many answers appreciated that nickel was a catalyst and annotated Fig. 3.3 to show a reduction in activation energy. Weaker responses produced a new curve and did not change the activation energy.

(ii) Answers which linked the difference in the size of area **B** with the rate of hydrogenation were seen either in answers which labelled area **B** on Fig. 3.3 or when stated explicitly in the answer space. Explanations in terms of collisions sometimes referred to the increase in frequency of successful collisions. It was more common to see incomplete reference to either an increase in the number of successful collisions or an increase in frequency of collisions.

(e) A significant proportion of candidates did not attempt this question. It was relatively common to see answers which showed one correct section of the alkene. Care needed to be taken to avoid producing a structure where the valency of each carbon atom was not 4, usually by the addition of an atom or group of atoms on a carbon atom of the double bond.

Question 4

(a) (i) This question proved to be straightforward and correct identification of the formula of reducing agent **Q** was common.

(ii) Construction of an equation to represent this reduction reaction was challenging for many. Some answers did not show H_2O as the additional product as well as an alcohol. Incorrect transcription of the formula of propan-1-ol and equations not balanced in terms of the number of hydrogen atoms were common errors.

(b) (i) Incorrect reference to step 1 as redox or addition were seen in weaker responses.

(ii) Some answers confused the reactants and conditions required to produce a nitrile from a halogenoalkane with those required to produce a hydroxynitrile from a carbonyl compound.

(iii) This equation proved to be demanding, and fully correct equations were seen rarely. Some answers correctly identified the organic product whilst not correctly identifying the formulae of the reagents and other products involved. Some answers described the formulae of all the reagents and inorganic products involved. The organic product was not always represented as an unambiguous structure.

(iv) Identification of the reaction as hydrolysis was seen. Incorrect names included hydration, redox, substitution, addition (only) and elimination (only).

(c) (i) Appropriate identification of the hybridisation shown by all carbon atoms in alcohols was seen in a significant proportion of answers.

(ii) Many answers correctly identified the gas produced in the reaction. Weaker responses did not engage fully with the question and identified the non-gaseous product.

(iii) Correct identification of sodium as a reducing agent was seen. Weaker responses identified sodium metal as a 'salt maker' or described sodium metal as a base.

(d) (i) Those candidates with a good understanding of the reaction of alcohols when heated with acidified $K_2Cr_2O_7$ and when warmed with alkaline I_2(aq) correctly deduced the structure of **A** as the tertiary alcohol 2-methylpropan-2-ol. A significant proportion of candidates did not attempt to answer this question.

(ii) Candidates found **(d)(ii)** slightly more challenging than **(d)(i)**. Reference to 'butanol' was ambiguous as there was no reference to whether this referred to the primary or a secondary alcohol.

Butanal was a common incorrect answer. A significant proportion of candidates did not attempt to answer this question**.**

(iii) Candidates also found **(d)(iii)** slightly more challenging than **(d)(ii)**. Some answers were contradicted when a correct name was given with an incorrect structure or vice versa. A significant proportion of candidates did not attempt to answer this question.

Question 5

(a) Candidates were required to interpret the skeletal formula of vitamin C to deduce the molecular formula and then work out the empirical formula from this. Many answers gave the molecular formula or showed both formulae without a clear indication of which of the two was the empirical formula.

(b) (i) Appropriate working to calculate the amount of I_2(aq) added was seen in many answers. Sometimes the answer was given to two significant figures when all the data given was to three or four significant figures.

(ii) Many candidates struggled to find the amount of vitamin C present in the 150 g sample. It was relatively common for candidates to ignore the reference to using 25 cm^3 of the total volume of solution **L** in the titration.

A number of candidates took the mass of vitamin C in the 150 g sample and expressed this as a percentage.

(iii) Many candidates indicated which absorptions present in the infrared spectrum of vitamin C would also be present in the spectrum for **M**. Some candidates misunderstood the question and completed the table by identifying the bond responsible for each of the absorptions in the empty column.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions

Key messages

- Structured questions give candidates the opportunity to show their knowledge and understanding over a wide range of syllabus topics. The best answers are concise and precise: there is often little need for fully developed sentences, providing that the sense and balance of answers are clear. The accurate use of chemical terminology remains crucial to remove ambiguity from responses; there is often little need to paraphrase.

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

- Working in calculations should be fully shown to ensure that due credit can be awarded, especially where a numerical answer might be obtained by different methods, correctly or incorrectly. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

This paper tested candidates’ knowledge and understanding of important aspects of AS Level Chemistry. All marks were awarded and candidates showed themselves able to gain credit on both AO1 and AO2 items, although AO1 items proved to be those where a greater strength was evident.

Diagrams should be labelled as fully as possible to avoid ambiguity or conflict with more extended writing. Similarly, mechanistic diagrams need careful attention, particularly in the placement of the origin and destination of curly arrows: candidates who perform less well are often imprecise, however, their underlying knowledge may not in fact be deficient.

Candidates experienced the greatest difficulty with data handling (e.g. interpreting melting points), organic synthesis routes and mechanisms (especially in **Question 6**) and conceptual explanations.

Comments on specific questions

Question 1

This question tested understanding of atomic structure, ionisation and periodicity. Candidates needed to give targeted responses to the latter, longer questions in order to gain full credit, rather than listing all factors affecting ions and ionisation.

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

(ii) Some over-interpretation of this question led to confusion, with some answers indicating (total number of electrons) ÷ 2.

(iii) This was well answered by a large majority of candidates.

(b)(i) Candidates are reminded to include state symbols in all equations representing these processes: this is an assumed requirement and will not necessarily be asked explicitly.

(ii) Nearly all candidates attempted an answer to this question, but many needed to focus on the salient factors (spin-pair repulsion etc.) rather than a general answer about ionisation-energy dependency.

(iii) A common misrepresentation was to have the ions in reverse order, although the reasoning was 'correct' for the correct order. A key point in candidates' answers was that of the isoelectronic nature of the ions: those candidates that were able to identify this were able to respond well.

Question 2

This question focused on the chemistry and physical properties of Period 3 oxides, including an assessment and interpretation of data trends to evaluate a scientific hypothesis. Most of the credit available could have been obtained by accurate recall of syllabus content: AO1 skills.

(a) This was well answered by most candidates.

(b) Candidates found this challenging. The excess of NaOH ensured the formation of Na_3PO_4, which then leant itself to balancing the species.

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

(ii) This proved challenging for candidates, with few completely correct answers given. There appeared to be confusion over giving 'false' or 'not enough evidence' as an answer — such questions are designed to be based on the information given.

(d) The majority of candidates answered this correctly.

(e)(i)(ii) Credit was obtained by stating the species required. Many candidates attempted to construct equations, but were not penalised for such attempts.

Question 3

A mixture of questions from across the different sections of the syllabus were presented here. Precision in answers was required, particularly in **3(a)(ii)**, **3(b)(ii)** and **3(b)(iii)**. This proved one of the most challenging questions overall, especially the definition of activation energy and interpretation of the Boltzmann distribution.

(a)(i) This was left unanswered by many candidates.

(ii) This question split candidates in their ability to recall information about PAN and its formation: whereas many answers gained full credit, others struggled to give a creditworthy response.

(b)(i) This was left unanswered by many candidates.

(ii) Candidates did not generally perform well here, although the definition of activation energy is a core concept at this and lower assessment levels. Precision of language is key.

(iii) There were many good attempts at this question, although a large variation in description. The most concise answers employed phrases such as 'frequency of effective collisions' and used well labelled diagrams.

Question 4

This question looked for skills in interpreting experimental data, specifically from a concentration–time graph, to calculate reaction rates and deduce the limiting reagent. Some stoichiometrical calculations, logical reasoning and use of data were also expected.

(a)(i) Many candidates answered this well. Common errors were not to calculate average but instantaneous rates (unnecessarily using tangents) and to change or present incorrect versions of the units. Candidates are reminded that the best representation of units is using indices,
i.e. mol dm^{-3} s^{-1} in this case.

(ii) This was well attempted, although with some overcomplicated reasoning given at times.

(iii) The best responses made descriptive links to Fig. 4.1, although this was not necessary to gain credit.

(iv) This question divided candidates: some were able to identify the limiting reagent quantitatively but not determine the number of atoms; others applied Avogadro's constant correctly to the wrong quantity.

(v) Few candidates were able to identify the water solubility of SO_2 as the key answer.

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

(ii) There were many confused answers here, although many candidates attempted reasonable responses. Although closely related, there is an appreciable difference between individual dipoles and the overall dipole moment: the best responses set these apart in their answers.

Question 5

This question tested structural interpretation through diagrams, chemical tests and spectroscopic data. The different parts within this question were designed to assess skills in organic synthesis and analysis. Candidates were notably weaker in interpreting infrared spectra and explaining electrophilic reactivity.

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

(ii) Many candidates gave correct observations, but many struggled with the structural formulae.

(b)(i) Candidates were much more adept at identifying the number of π bonds than that of the σ bonds.

(ii) The identification of **Y** proved problematic.

(iii) This was competently answered by a large proportion of candidates.

(iv) Candidates are reminded to give full detail of reagents **and** conditions.

(v) This was notably well answered. Candidates are reminded to use the data provided fully and to use the terms provided in the question.

(vi) This showed a large variation in understanding and the ability to render addition polymers (only two C atoms in the backbone's repeat unit) correctly.

(c) Answers to this question often lacked conceptual depth. Candidates showed a tendency to overcomplicate their responses.

Question 6

Knowledge of different organic mechanisms underpinned this question, which looked to assess candidates' ability to interpret reaction pathways and synthetic planning over multiple steps, including addition and substitution/hydrolysis reactions. Questions were frequently omitted here, perhaps indicating low confidence with multi-step organic reasoning.

(a)(i) Candidates needed to be specific with their description here: **one** product forms from the combination of two (or more) species.

(ii) Candidates who performed well overall answered this well.

(iii) Candidates who attempted this performed well; others omitted this question.

(b) Many candidates omitted this question. There is a tendency to repeat the reagents in the middle step, whereas this is the space given for the intermediate. Candidates are reminded that curly arrows show the movement of electron pairs: they do not originate from centres without electrons.

(c)(i) Although the primary reagent was well understood, the accompanying conditions were often incorrect.

(ii) This was well answered.

(iii) This question was often left unanswered. Under acidic conditions, candidates are reminded of the formation of NH_4^+ rather than NH_3.

CHEMISTRY

Paper 9701/24
AS Level Structured Questions

Key messages

- Candidates are encouraged to learn accurately the definitions and details as specified in the syllabus.
- Responses should be legible and clearly laid out to eliminate ambiguity.
- Candidates are encouraged to respond directly to an instruction. When a molecular formula is asked for, no other type of formula such as structural or skeletal should be drawn.

General comments

Chemical equations must always be balanced, both for atoms and for charge.

Comments on specific questions

Question 1

(a) This was mostly well answered but a noticeable number of candidates omitted ‘giant’ in giant metallic, thereby not addressing the question which asked for lattice structure. Some candidates thought metals were ionic.

(b) The most common error was to miss the idea that the delocalised electrons must move when conducting electricity. Some candidates did not give a correct reason for both the conductivity of the metals Na to A*l* and the lack of conductivity of the non-metals P to C*l*. The word delocalised was used correctly by many but candidates who performed less well used terms such as free electrons or sea of electrons, neither of which gained credit.

(c) (i) The majority of answers gave a correct representation of the third ionisation energy of argon. A few forgot to add the gas state symbol to both species. Errors included removing three electrons from the neutral atom.

(ii) This question was strongly answered by the cohort. Some omitted to state that nuclear charge affects the strength of attraction between the nucleus and the outer electron. A vague response like ‘distance’ was insufficient to gain credit.

(iii) Candidates were required to use the Fig. 1.2 given to suggest the most significant factor affecting the size of the attraction between the nucleus and outer electron. There were many candidates who did not address the figure at all and many more who did not appreciate that the question was referring to the third ionisation energy. They needed to focus on the figure which showed a steep decline from Mg to A*l* which meant that the third electron in Mg (and Na) is removed from the 2p orbital whereas the third electron in A*l* was removed from the 3s. Incorrect orbitals were penalised. A strong response needed a specific reason to why and how the shielding effect or distance to the outer electrons from the nucleus relates to the data given. Responses from many candidates were extended but confused and not comparative.

(iv) Fully correct responses were seen from most candidates.

(d) (i) The equation for the reaction of phosphorus with oxygen was well known

(ii) This, more challenging, equation for the reaction of aluminium oxide with an excess of sodium hydroxide was also well known.

Question 2

(a) (i) Many candidates appeared to have looked at the diagram and decided the molecule was linear in shape. It is important that candidates consider the effect of lone pairs on the shape of a molecule.

(ii) Those that gave an angle of 180° did not consider the effect of the lone pairs. However, most candidates did give a correct bond angle between 100° and 105°.

(b) (i) The question was well answered by candidates who knew that a solid appeared, but some did not get the colour right. A yellow solid was the answer required. A number of candidates correctly used the term 'colourless' or 'decolourised' in referring to the disappearance of the red colour of SCl_2 rather than the incorrect 'clear'.

(ii) Candidates demonstrated a good understanding of how to work out oxidation states in compounds.

(iii) Correct identification of this reaction as hydrolysis was common.

Question 3

(a) (i) This calculation proved undemanding although candidates are reminded of the need to consider the data given when deciding on the number of significant figures to use with their answer.

(ii) Better performing candidates managed this concentration calculation question with ease. A few candidates used the alternative figures given and gained full credit. Some candidates omitted to address the stoichiometry in the equation provided and divided by 2 before scaling up to 1 dm^3.

(b) Candidates needed to realise that 0.3 mol of HI was present initially. Many did recognise this and had clearly laid out working. However, some candidates gave no clear structure to their calculation with no line of reasoning which could be followed. Some candidates subtracted 0.3 mol instead of adding.

(c) This was mostly correct. It is important that candidates are encouraged to use appropriate significant figures in line with the data in the question.

(d) (i) The definition of a covalent bond was not well known. The following are expected to be seen in the definition: (electrostatic) attraction, nuclei (of two atoms) and a shared pair of electrons.

(ii) The thermal stability of the hydrogen halides was well understood as a decreasing trend down group 17 and candidates correctly related this to increasing bond length or atomic size of the halogen atom. However, they rarely went on to explain how this led to decreasing attraction between the nucleus and the shared electron pair. Reference to halide ions was penalised and electronegativity was ignored.

(iii) The suggested value for the equilibrium constant for the dissociation of HBr was mostly within an accepted range although some candidates did not appreciate that they had to take the reciprocal of the K_c value for HI as the equation was expressed the other way around.

Question 4

(a) This was mostly correct. Anything other than a molecular formula was penalised.

(b) Many candidates struggled to correctly name propyl ethanoate. There was a wide range of responses and a few put ethyl propanoate. Propanyl was seen frequently in place of propyl and was not given credit.

(c) (i) Correct identification of this reaction as a condensation was common. A few cited esterification despite this information being present in the stem.

(ii) The most common error, seen many times, was to omit the water in this esterification equation. Candidates were perhaps so focused on getting the structure of the ester right that they forgot to check to see if the equation was balanced.

(iii) Propanol was the most common answer but the systematic name was asked for and thus propan-1-ol was required.

(d) (i) Candidates who performed well on the whole paper knew this reaction and constructed an equation for the acid hydrolysis of CH_3CN perfectly. Others really struggled and ended up with non-existent products or, commonly, HCN.

(ii) Fully correct answers required the O-H bond to be displayed alongside the rest of the displayed molecule. A few did not draw propan-2-ol but another alcohol.

(iii) The reagents and conditions required for this synthesis are clearly laid out in the syllabus. There were several acceptable sets of reagents and conditions for step 1 which would lead to the formation of chloromethane. Of those who chose hydrogen chloride as a reagent, many omitted to state that HCl should be in the form of a gas. Confusion around the relevant reagents and conditions was seen in weaker responses. In step 2, many candidates appeared to be confusing the reaction with that between CN^- and a carbonyl compound leading to a hydroxy nitrile where the reagent would be HCN. KCN or NaCN needed to be stated as the reagent. Ethanol and heat were required conditions for step 2 and were frequently omitted.

Question 5

(a) This was well answered with most candidates choosing to draw skeletal representations of two positional isomers of **W**. Both the cis or trans version of hept-3-ene were accepted. Although any form of structure was accepted here, candidates should be careful to ensure that their response is unambiguous. Parts of the chain shortened to C_5H_{11} led to ambiguity and was not credited.

(b) (i) Candidates seemed to struggle to access what was required here. The question demanded a syllabus statement that there was restricted rotation around the double bond. Many candidates did not seem to understand the emphasis of the question.

(ii) This was a demanding question requiring unambiguous reasoning as to either why **W** does show stereoisomerism or why one of the positional isomers does not. Answers in which it was not clear whether they were referring to **W** or to one of the positional isomers did not gain credit. Many candidates did not use precise enough language to access credit. Ambiguous use of the term ‘side of the double bond’ should be avoided, replaced with the much sharper ‘each end of the double bond’ or ‘both carbons of the double bond’. Candidates should not use the term functional group here when they mean group. A minority had not absorbed the question stem sufficiently well and answered in terms of chirality, which was clearly wrong.

(c) A large number of candidates understood how to draw a skeletal structure. A few mistakenly drew the cis version of hept-3-ene rather than hept-2-ene.

(d) (i) There were many correct answers to this question.

(ii) Candidates were very familiar with this reaction and many performed well.

Question 6

(a) (i) The definition of empirical formula was not well known. Many definitions referred to the simplest ratio of elements and not atoms.

(ii) Whilst the definition of empirical formula was not well known, the concept was clearly understood as most candidates were able to produce a method which produced the correct ratio of 1 : 2 C : H. In this paper, it was tested as a simple calculation and so short approaches were satisfactory, but candidates should be encouraged to set out their working in a clear, perhaps tabulated, form if more challenging data is provided as it is not always easy to follow the candidate’s logic.

(iii) Most responses were correct. A few incorrectly cited alkanes and some did not understand the term homologous series which led to random answers such as chain or position isomer.

(b) The majority of responses were correct. Some forgot to convert their temperature to Kelvin. A small number struggled to rearrange the expression to find n.

(c) (i) Most candidates did obtain 10 as their final answer but some gave unconvincing methods in their working. Some appeared to be guessing, using 138 or 139 in their calculations. However, the majority used the fact of 1.10% carbon-13 occurrence in a correct expression to calculate n.

(ii) The majority of responses were correct.

(iii) This was generally well worked out by candidates although a significant number omitted the + sign on the fragment. Candidates should know that the species that are detected in a mass spectrometer are positively charged.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- ensure they follow the instructions in the method
- show the precision of the apparatus used in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of suitable observations given in the guidance on the qualitative analysis in the examination paper
- use blue or black pen to complete the paper as instructed on the front cover. Use of pencil is only appropriate for graphical work.

General comments

This paper generated a wide range of marks with a small number of candidates gaining full credit in at least one quantitative question. Many candidates found the qualitative analysis question more demanding, although a few gained nearly all the credit available. Almost all candidates were able to complete the paper within the time allowed.

Supervisor results are required for both the quantitative and qualitative tasks to award accuracy marks in **Questions 1** and **2** and as a check on the 'unknowns' and reagents in **Question 3**. Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that the results can be compared and the quality of candidates' practical work assessed fairly. It is advisable that the best practical chemist in the centre carries out the experiments.

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

Comments on specific questions

Question 1

Candidates found aspects of this question challenging.

(a) Candidates are expected to give precise labels to their experimental data. Errors included describing mass as weight and volume as ml. Some candidates did not record the volume of gas. Almost all candidates consistently recorded their balance readings to the expected two decimal places. Use of a one decimal place balance is only acceptable if the lack of a two decimal place balance is noted in the supervisor report. Candidates are required to record their gas volume as an integer in cm^3. Credit for accuracy was not awarded to some candidates as their recorded volume of gas was lower than allowed.

(b) (i) Errors made when calculating the amount of carbon dioxide included the use of $0.500\,mol\,dm^{-3}$ HCl instead of dividing by 24 000. Many did not appreciate that the amount of carbon dioxide equalled the moles of calcium carbonate. Some only quoted the answer to one decimal place.

(ii) Many candidates did not use the M_r of calcium carbonate (100.1) in their calculation of the percentage purity of calcium carbonate and calculated percentage purity using the amount of calcium carbonate in mol in **(b)(i)**, instead of converting to the mass of calcium carbonate.

(c) This was challenging for candidates. Candidates regularly incorrectly ticked the middle box. Few candidates who correctly ticked the bottom box appreciated that it would result in a faster reaction and more gas would escape before the bung was replaced, with less gas being collected. The consequence being the decrease in the calculated percentage purity.

(d) (i) Many candidates gained credit for suggesting unreacted calcium carbonate would be left in the flask. Several candidates referred to less fizzing or lower volume of carbon dioxide produced, but did not engage with an observation when the acid is not used in excess.

(ii) Very few candidates were successful in this part. Having referred to a decrease in percentage purity, few candidates then considered that not all the calcium carbonate has reacted when the acid is not in excess, leading to less gas being collected and this had the effect of less mass of calcium carbonate being calculated.

Question 2

Most candidates were well prepared to carry out the titration experiment.

(a) A large proportion of candidates were awarded full credit for recording their titration results in an appropriate format. Some candidates omitted the burette readings for the rough titre (candidates are instructed to do this in the method) or for not recording accurate burette readings to either #.#0 or #.#5 cm^3. Some candidates did not label their results table accurately or omitted the titre values. Many candidates appeared to refill their burettes to 0.00 cm^3 for each accurate titration. Filling to 0.00 cm^3 is an unnecessary use of valuable time. Some candidates recorded their initial burette reading as 50.(00). A few candidates did not obtain concordant titres as their final accurate titre was more than 0.10 cm^3 from any previous value. Once concordance in the accurate titrations has been achieved there is no reason to continue with further titrations. A large majority of candidates were awarded some credit for accuracy.

(b) Candidates performed well here. The errors seen were too wide a spread of accurate titres used for the mean or giving the answer to one decimal place. A few candidates inappropriately rounded their mean titre to the nearest #.#0 or #.#5 cm^3, e.g. 25.53 was rounded to 25.55 cm^3, or inappropriately recorded the mean titre as 26.675 instead of rounding to 0.01 cm^3 i.e. 26.68.

(c) (i) Many candidates gave at least one of their answers in **(c)(ii)**, **(c)(iii)**, **(c)(iv)** and **(c)(v)** to one or two significant figures e.g. 0.5 in **(c)(iv)**, so were not awarded credit. Given the precision of the apparatus and concentrations of the solutions used, answers to three or four significant figures were appropriate.

(ii) Most candidates used the correct figures in their calculations and rounded correctly.

(iii) Very few candidates answered this correctly. The dilutions in the experiment from **FA 3** to **FA 5** were generally not appreciated, and many candidates did not use the appropriate values when answering the two parts of the question. Many did not use **(c)(ii)** when calculating the amount of HCl and errors included calculating the moles of HCl used to prepare **FA 3**.

(iv) Most candidates answered this correctly.

(v) Many candidates appreciated a subtraction was required, but some incorrectly used **(c)(iii)** – **(c)(iv)**.

(vi) Most candidates correctly applied the stoichiometry given in the equation.

(vii) Many candidates did not use the M_r of calcium carbonate (100.1) in their calculation of the percentage purity of calcium carbonate and calculated the percentage using the amount of calcium carbonate in mol in **FA1** in **(c)(iv)** instead of converting to mass of calcium carbonate.

(d) (i) Very few candidates were awarded full credit for this question. Responses often referred to gas being lost, but not specifically when the bung was being replaced. Incorrect answers based on the precision of the apparatus or poor handling of the equipment were often given.

(ii) Many candidates correctly suggested a gas syringe. Incorrect answers based on improving the precision of the apparatus or the handling of the equipment or repeating to eliminate anomalies were often given.

Question 3

Candidates should be encouraged to read and make use of the guidance given at the start of the qualitative analysis section. Use of the qualitative analysis notes in the examination paper would have helped some with correctly describing their observations. While some candidates had considerable difficulties in describing the changes they saw, others performed well. Candidates are reminded to add reagents carefully, noting changes as they occur; sometimes reactions may not be immediate or there may be a series of changes. Candidates should be reminded that no additional tests should be attempted e.g. adding aqueous ammonia in **Test 3** with silver nitrate. Candidates should also be reminded that dark, clear and foggy are not colours. ‘Gas released’ is not credited in place of effervescence/fizzing/bubbling. ‘No observation’ is not the same as ‘no (visible) change.’

(a) (i) **Test 1**: It is important to describe the state in addition to the colour of a substance. On carefully adding aqueous ammonia, a pale blue **precipitate** is observed which is soluble in excess forming a dark blue **solution**. Candidates regularly observed the dark blue solution having initially added excess aqueous ammonia to the test-tube.

Test 2: On adding aqueous sodium hydroxide, a pale blue precipitate is observed which is insoluble in excess. Candidates often did not record the insolubility in excess aqueous sodium hydroxide. On warming, this forms a black solid and gas/fizzing which turns red litmus blue. Many observed the litmus turning blue, but did not mention the gas.

Test 3: On adding silver nitrate, a white precipitate is observed. Some candidates referred to the precipitate being insoluble in excess, but no credit was awarded if aqueous ammonia was also added.

Test 4: Most candidates correctly stated ‘no change’.

Test 5: Most candidates correctly stated ‘no change’ in dilute nitric acid before and after standing.

Test 6: ‘Yellow’ and ‘orange’ are not suitable descriptions of the colour of aqueous iodine. However, many candidates were credited for blue-black on adding starch solution.

(ii) Few candidates gave a correctly balanced equation with correct state symbols. The equation for the formation of silver chloride was the most common correct answer but was sometimes missing one or more state symbols. Some candidates correctly gave an equation for the formation of copper(II) hydroxide but the hydroxide ions were not correctly balanced.

(iii) Candidates performed well here. Cu^{2+} and Cl^- were regularly correctly identified. Incorrect answers included NO_3^-, I^-, Cr^{3+} and ‘unknown’. Very few candidates were awarded full credit.

(b) (i) Very few candidates observed condensation and referred to fizzing or effect on litmus paper.

(ii) Most candidates identified fizzing when adding nitric acid to **FA 9**. Many tested the gas for carbon dioxide using limewater but recorded it turning milky as opposed to the formation of a white precipitate.

(iii) Candidates regularly deduced the formula of **FA 8** as Na_2CO_3. Those who suggested $NaHCO_3$ often had insufficient evidence for their deduction in **(b)(i)** and **(b)(ii)**.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

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

General comments

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

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

This paper generated a wide range of marks, with a small number of candidates gaining full credit in at least one quantitative question. Many candidates found the qualitative analysis question more demanding, though a few gained nearly all the marks available. Almost all the candidates were able to complete the paper within the time allowed.

Comments on specific questions

Question 1

Candidates were generally well prepared for the titration procedure and subsequent calculations. However, many candidates found the analysis and evaluation questions that followed challenging.

(a) Many candidates performed well on the presentation of their titration results. However, candidates should be reminded that the burette readings for the rough titration must be recorded either in the space provided or clearly labelled in the main titration table.

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

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

(c) (i) Most candidates used some of the relevant information given in the question. $7.50 \div 192$ and $7.50 \times 25.00 \div 1000$ were common answers worthy of 1 mark. Candidates should be aware of the need to give their answers to an appropriate number of significant figures throughout the paper.

(ii) Most candidates answered this part correctly. Some candidates were not awarded credit because they had rounded during the calculation. Candidates are advised to use the calculator answer to continue a calculation, or to round to a greater number of significant figures than the final answer, rather than over-rounding midway through a calculation.

(iii) Candidates were expected to divide their answer to **(c)(ii)** by **(c)(i)** and to comment on their calculated mole ratio. Another valid approach was to multiply **(c)(i)** by 3 and compare the answer with the value in **(c)(ii)**. Not all candidates completed the task, with some not realising that to support the statement, three moles of sodium hydroxide should react with each mole of citric acid.

(iv) Some candidates ignored the statement that citric acid is triprotic and used their result in **(c)(iii)** to write the equation. Many of those supplying the correct formula for the sodium salt did not go on to balance the equation. Only the better performing candidates gained the credit here and in **(c)(v)**.

(v) Very few candidates supplied a formula for citric acid that did not contain a chiral carbon atom. Structures that did not contain three carboxylic acid groups were very often seen, as well as incorrect numbers of C, H and O atoms, cyclic structures and structures with double bonds in the carbon chain.

(d) Candidates were expected to indicate explicitly whether they agree with the student. They then needed to demonstrate their understanding that each reading of a burette has an uncertainty of $\pm 0.05\,cm^3$ and that two readings are taken per titre making the total uncertainty greater for the use of a pipette than a burette, so the student's suggestion is incorrect.

Question 2

Use of the tare facility on balances should be discouraged as errors may be incurred if several candidates are using the same balance.

(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.

Many candidates were able to write clear headings with correct units and record readings of temperature and mass to the correct degree of precision. Errors in headings and units included 'initial/final mass,' use of 'weight' instead of mass, and 'C°'. 'Final temperature of **FB 5**' is not an acceptable heading, as following the reaction, **FB 5** was neutralised and formed a salt and therefore the solution is no longer **FB 5.**

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

Centres should be aware that Fahrenheit is not a suitable unit of temperature for this paper.

(b) (i) Many candidates correctly calculated the energy change. A common error was to use the mass of **FB 4** as well as or instead of the 30 cm^3 (30 g) of distilled water. The value given for c ($= 4.18\,kJ\,kg^{-1}\,K^{-1}$) is for water and not for the solution. Some candidates incorrectly used $c = 4.2\,kJ\,kg^{-1}\,K^{-1}$; candidates are expected to use the data supplied in the paper. Another error was to write down all the numbers on the calculator rather than considering how many significant figures were appropriate in this question.

(ii) A notable minority of candidates divided their energy change from **(b)(i)** by 1 mole, instead of calculating and dividing by the number of moles used in their experiment. Other errors included omitting the division by 1000, or giving the sign for ΔH_1 as negative.

(c) Some candidates who used the tare facility on the balance recorded two values which were not identical so the mass of **FB 5** could not be verified. A large majority of candidates gained at least one mark for accuracy. A suitable value for the ΔT ÷ mass ratio was used with candidates in centres reporting the use of citric acid monohydrate.

(d) Candidates who performed well in **(b)** also performed well in this part. Some candidates calculated the amount of sodium hydroxide used: this was inappropriate as the NaOH(aq) was stated as being in excess.

(e) Generally, only the better performing candidates calculated the enthalpy change for the reaction correctly. Common errors were adding ΔH_1 and ΔH_2 or calculating $\Delta H_1 - \Delta H_2$.

Question 3

A greater awareness of the introductory information would have benefited many candidates. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, a solution is always clear but not always colourless. ‘Gas released’ is not an observation and is not credited in place of ‘effervescence’. ‘No observation’ is not the same as ‘no (visible) change’.

‘Ppt’ is a commonly accepted abbreviation for ‘precipitate’. However, candidates should avoid using other abbreviations, particularly where there is ambiguity. For example, ‘sol’ was seen as an abbreviation for both solid and solution. The appropriate observation would be to use the whole word.

(a) (i) This part showed good discrimination across candidates; the full range of marks were seen, from 0 to 6.

Use of the qualitative analysis notes enabled candidates to select colour observations and descriptions of gas tests more likely to gain them credit. Candidates should consider what familiar reagents are being tested for and the probable observations, e.g., if aqueous silver nitrate is used, it is to test for a halide anion and either white, cream or pale-yellow precipitates are likely observations. A number of candidates gained all the credit available for **FB 7** Test 4 having matched their observations with those described in the ‘Reactions of cations’ table.

Common errors were:

- incorrect colours for products of a reaction. I_2(aq) (formed in Test 1) is neither ‘red’ nor ‘orange’ and ‘ppt’ was inappropriate here
- only giving one observation on adding aqueous sodium thiosulfate to **FB 7** in Test 1 or aqueous ammonia in Test 4. Unless instructed otherwise, candidates should add reagents dropwise and then to excess
- ignoring the change in colour of the solution when performing Test 2 on **FB 7** and not testing the gas formed when performing Test 2 on **FB 8**
- adding an additional reagent (NH_3(aq)) to the product with **FB 8** in Test 3. It is clearly stated on page 6 that ‘no additional tests should be attempted’.

(ii) Many candidates successfully used their observations from Tests 3 and 4 and the qualitative analysis notes to identify the ions and correctly construct the formula of **FB 8**. A small number of candidates gave the name of the compound; however, the question requires the formula.

(iii) Few candidates answered this correctly.

(iv) Few candidates answered this correctly. A common error was the incorrect choice of ions; the ionic equation had to refer to one of the reactions in Test 4. Other common errors were omission of state symbols and incorrect stoichiometry, especially for the OH^-(aq) ion.

(b) (i) The qualitative analysis notes were helpful here. The tests in **(a)(i)** rule out the possibility of a halide or a carbonate, and the question states that the anion does not contain sulfur. This leaves only nitrate or nitrite as possible anions. Many candidates successfully used NaOH(aq) and A*l* to show the presence of nitrate or nitrite, and then used acid or $KMnO_4$(aq) to distinguish between them.

Common errors included:

- writing OH^- instead of NaOH. When describing a chemical test, the complete reagent is required
- omitting ‘warming’
- not making it clear that a gas was tested with litmus paper
- not specifying which acid was used to distinguish NO_2^- from NO_3^-
- insufficient care when writing the name or formula of potassium manganate(VII). For the formula, the correct capitalisation is required. For the name, the oxidation state is essential
- not making it clear that the test involving potassium manganate(VII) was carried out on a separate sample of **FB 7**, rather than added to the test-tube following reaction with NaOH and aluminium foil.

(ii) Many candidates successfully deduced the correct formula for **FB 7**.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

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

General comments

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

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

This paper generated a wide range of marks, although few candidates achieved very low or very high marks. A small number of candidates gained full credit in at least one quantitative question. In common with past papers, many candidates found the qualitative analysis question more demanding, though a few gained nearly all the marks available. Almost all candidates were able to complete the paper within the time allowed.

It is important that candidates are acquainted with the information in the initial Quantitative analysis and Qualitative analysis notes given in advance of **Question 1** and **Question 3**. These sections are designed to aid the candidates in their work as are the Qualitative analysis notes given prior to the table of data and Periodic Table at the end of the paper.

Comments on specific questions

Question 1

Candidates generally appeared to be well-prepared in both the practical aspects and the subsequent calculations in this question. However, more attention to the instructions and information given was needed in some parts.

(a) Most candidates seemed well versed in how to present results for a titration question. Column headings were good; however, some candidates used ‘initial’ rather than ‘initial volume’. ‘Amount’ instead of ‘volume’ was also seen – candidates should be aware that amount refers to moles. The best heading for the volume added is ‘titre’. There were some centres where few candidates recorded their accurate burette readings to the nearest 0.05 cm^3. For most candidates two or three titrations were sufficient to achieve concordant results. Those performing additional titrations run the risk of the final titre being more than 0.10 cm^3 from any other.

(b) Most candidates calculated a mean value. Incorrect rounding and answers given to one decimal place were the usual errors seen.

(c) (i) Many candidates started giving their answers to the expected 3 or 4 significant figures. However, fewer recorded all three answers to the same precision.

(ii) Most candidates answered this correctly. A few did not convert their mean titre to dm^3 or made errors in rounding.

(iii) Many candidates used the stoichiometry given in the question correctly.

(iv) Far fewer candidates calculated the concentration of hydrogen peroxide **FA 1**, possibly owing to insufficient care when reading the question. Many did not include the dilution factor in their calculation so calculated the concentration of hydrogen peroxide in **FA 4** rather than in **FA 1** as instructed.

(d) Very few answered this correctly. Some correctly stated the student’s suggestion was incorrect as the acid was in excess. Of those attempting the calculation to show the excess of acid, the inclusion of it being diprotic was usually omitted. Most candidates answered this question in terms of the relative precision of pipettes and measuring cylinders so could not access credit.

Question 2

This question proved challenging for candidates, especially in the section dealing with sources of error and the accuracy of the procedure when one of the variables is changed.

(a) Many candidates gained credit for headings and units for their tables of results. The most common errors were writing C° for the temperature unit and omitting the changes in temperature. Almost all gained credit for clearly linking the volumes of **FA 1** with the associated thermometer readings. Some candidates did not record their thermometer readings to the expected .0 or .5 °C. It was notable that a large minority of candidates did not achieve similar temperature changes for the two experiments. The two ΔT values should be the same within ± 1 °C as the increase in amount of hydrogen peroxide decomposing is compensated by the increase in volume. However, many candidates were able to gain credit for the mean increase in temperature compared with that of the supervisor.

(b) (i) Many candidates calculated the energy change. The most common errors were using $c = 4.2\,kJ\,kg^{-1}\,K^{-1}$, adding 273 to the temperature change for **Experiment 2** or giving the answer to five significant figures. Candidates are expected to use the data supplied in the paper.

(ii) Few candidates gained full credit, although many showed clear working towards the correct answer, usually by the division of **(b)(i)** by 98.2 or 98 200.

(c) (i) In this type of question, candidates should try to relate their answer to the procedure (including the calculation) they have just carried out. It is usual that the amount (number of moles) of substance will be needed as part of the answer. Here, a good starting point is noting a smaller change in temperature is expected owing to heat loss. The calculation in **(b)** linked this to a smaller change in energy, hence a smaller amount of hydrogen peroxide in the volume used and thus a lower concentration. Some candidates worked their way through some of the points but only concluded that the concentration had changed without specifying in which direction. Many candidates did not gain credit as they discussed errors in the use of equipment.

(ii) This was poorly answered. Candidates must indicate explicitly whether or not they agree with the student. There were several valid ways to answer the question: the most commonly awarded answer linked the decrease in ΔT with the increase in its percentage error.

Question 3

A greater knowledge of the introductory information would have benefited many candidates. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, adding a solid to a solution and calling it a precipitate is incorrect.

(a) (i) Very many candidates stated the solution or filtrate turned (dark) green. Very few candidates gave a correct second observation, with ‘red’ or ‘brown’ being common incorrect observations.

(ii) From the observations recorded, it appeared that some candidates did not heat the mixture long enough for sufficient $Fe^{2+}(aq)$ to be formed. Some candidates suggested a gas was evolved or gave the colour of the residue on filtering. The filtrate was often described as green or colourless. Many candidates noted the formation of a brown or red-brown precipitate in the second part but far fewer noted the effect of adding excess aqueous sodium hydroxide.

(iii) The most common incorrect answers were ‘catalyst’ and ‘reducing agent’.

(iv) Few candidates gave a correct ionic equation. Common errors were omission of state symbols and incorrect stoichiometry, especially for the $OH^-(aq)$ ion. Those giving the equation for neutralisation rather than precipitation were generally more successful.

(b) (i) Almost all candidates attempting this part were able to gain at least one mark though very few gained all six. Use of the information given on pages 14 and 15 would have enabled candidates to select colour-descriptions or results of gas tests more likely to gain them credit.

Common errors were:

- ‘orange’ for the precipitate of $Fe(OH)_3(s)$ and/or for $I_2(aq)$
- NH_3 ‘identified’ when warming either or both **FA 6**/**FA 7** with NaOH(aq)
- ‘turns purple’ on adding the reagent $KMnO_4(aq)$ to **FA 6** instead of ‘(solution) remains purple’
- ‘fizzing’ missed in **Test 3** with **FA 7** and (less evident) in **Test 4** with **FA 6**.
- gas tests omitted or incorrectly described.

It is the responsibility of those running the examination at the centres to ensure the reagents are of the correct standard. For example, if $H_2O_2(aq)$ does not bubble on adding a little $MnO_2(s)$ then it is likely to have already decomposed and a fresh supply is needed.

(ii) Candidates should be encouraged to read the instructions carefully as many incorrectly added a second reagent, usually $NH_3(aq)$, after adding the expected $AgNO_3(aq)$. When the solution above the precipitate is coloured, candidates should look at the base of the test-tube to discern the appearance of the less-contaminated part of the precipitate.

(iii) Many candidates were able to identify Fe^{3+} and either or both Cl^- and I^-. Far fewer identified H^+ even when effervescence was recorded on adding $Na_2CO_3(aq)$. A number of candidates also identified K^+ even though there were no tests in the paper for this ion.

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Paper 9701/34
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

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

General comments

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

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

This paper generated a wide range of marks, although few candidates achieved very low or very high marks. A small number of candidates gained full credit in at least one quantitative question. In common with past papers, many candidates found the qualitative analysis question more demanding, although a few gained nearly all the marks available. Almost all candidates were able to complete the paper within the time allowed.

It is important that candidates are acquainted with the information in the initial Quantitative analysis and Qualitative analysis notes given in advance of **Question 1** and **Question 3**. These sections are designed to aid the candidates in their work, as are the Qualitative analysis notes given prior to the table of data and Periodic Table at the end of the paper.

Comments on specific questions

Question 1

Candidates generally appeared to be well-prepared in both the practical aspects and the subsequent calculations in this question. However, more attention to the instructions and information given was needed in some parts.

(a) Most candidates seemed well versed in how to present results for a titration question. Column headings were good; however, some candidates used 'initial' rather than 'initial volume'. 'Amount' instead of 'volume' was also seen – candidates should be aware that amount refers to moles. The best heading for the volume added is 'titre'. There were some centres where few candidates recorded their accurate burette readings to the nearest 0.05 cm^3. For most candidates, two or three titrations were sufficient to achieve concordant results. Those performing additional titrations run the risk of the final titre being more than 0.10 cm^3 from any other. Candidates should be reminded that they also need to include burette readings for their rough titre. This can be done either in the space provided or in their results table.

(b) Most candidates obtained the mean value. Incorrect rounding and answers given to one decimal place were the usual errors seen. A small number of candidates did not provide an indication of which titres had been used to calculate the mean.

(c) (i) Most candidates realised that an 'appropriate' number of significant figures meant three or four. However, some candidates rounded their answers to one or two significant figures.

(ii) Most candidates answered this part correctly. Occasionally, a value ending in 5 was rounded down rather than up.

(iii) The majority of candidates correctly used the stoichiometry given in the equation to multiply by 5. However, a much smaller number of candidates then also scaled up by 1000 ÷ 25 to get the correct final answer.

(iv) Candidates generally performed well here, although multiplication by the M_r of hydrated iron(II) sulfate was sometimes seen. Candidates should be reminded to use the data in the Periodic Table provided when answering this type of question.

(v) This was generally done less well than the rest of **(c)**. Candidates should be reminded that the information required to answer this type of question is often found in the information provided at the start of the question. Some candidates misinterpreted what they were being asked to do and stated that their answer was not equal to 150 mg rather than answering the question.

(d) Very few candidates gave a correct suggestion that both acids are strong. A small number of candidates also gave good answers in terms of the proticities of the two acids. Suggestions in terms of the redox chemistry were rare.

Question 2

(a) Candidates generally performed well in **(a)** with most gaining at least three marks. Occasionally, candidates did not record all their thermometer readings to one decimal place ending in 0 or 5. Some candidates selected volumes of **FB 5** greater than 10.00 cm^3 for their additional experiments.

(b) (i) Although there were occasional slips in the labelling of axes and the plotting of points, most candidates were well-prepared in the basics required to draw a graph. Some candidates missed the instruction to allow for a temperature 2 °C greater than their largest maximum temperature. Candidates fared least well with their lines of best fit. Candidates should be reminded that all their points should either be included when drawing their lines of best fit or they should be labelled as anomalous.

(ii) Nearly all the candidates who had an intersection on their graph correctly read off the volume on the *x*-axis.

(c) (i) Most candidates calculated this correctly, although sometimes the amount of sodium hydroxide was given as either double or half the amount of hydrochloric acid.

(ii) Although the expression for working out the energy change was known to most candidates, only a small proportion obtained a correct answer. By far the most common error was not realising that the total volume used in each experiment was $20.00\,cm^3$.

(iii) The method for working out the enthalpy change from the energy released and the number of moles was familiar to most candidates. Very few candidates made a mistake with the sign of the enthalpy change. Occasionally candidates did not convert their energy change to kJ.

Question 3

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

(a) (i) Most candidates recorded effervescence for the appropriate tests, noted ‘no change’ when required and observed the green precipitate with **FB 7** in **Test 3**. Better performing candidates also recorded correct gas tests and noted the green precipitate turning brown on contact with air.

(ii) This question proved difficult for most candidates and many were unable to deduce much from their observations. The correct identities of **FB 6** (possibly from the smell) and **FB 7** were seen more frequently than **FB 8**.

(b) (i) As was the case in **(a)(i)**, most candidates reported the fizzing but far fewer went on to try and test the gas produced. Amongst those who did test for carbon dioxide, many candidates reported the limewater going cloudy or milky rather than producing a white precipitate. The correct test for carbon dioxide is clearly stated in the Qualitative analysis notes.

(ii) Candidates performed reasonably well here although some did not perform the second part of the test. It is worth noting that for the halide test, candidates should decide whether the precipitate is white, cream or pale yellow. Answers such as cream-white or creamy white are not credited.

(iii) Occasionally, in **Test 1**, candidates did not write ‘no change’ in the top box. Regarding the second box, candidates should be reminded that when doing the test for ammonia, they should make it clear that they are testing the gas produced and not the solution. Candidates performed well on **Test 2**, with most recording one of the accepted colours for the final solution.

(iv) The conclusions here were generally more accurate than in **(a)(ii)**. Candidates should take care when writing formulas that the use of subscript (for numbers) and superscript (for charges) is accurate. Some candidates were not awarded credit here by guessing the identity of one of the cations when there was no test for it and so ‘unknown’ should have been recorded.

(v) A correct ionic equation with state symbols was only given by a minority of candidates. State symbols were often missing or incorrect.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

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

General comments

Supervisor results are needed for both the quantitative and qualitative tasks. These results are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the ‘unknowns’ and reagents in **Question 3**. Supervisors should carry out the experiments using the same solutions, solid samples and equipment as the candidates so that supervisor/candidate results and observations can be compared and the quality of candidate’s practical work be assessed fairly. Supervisors should ensure that more than one titration is carried out and that their results are concordant. It is advisable that the best practical chemist in the centre carries out the experiments.

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

This paper generated a distribution of marks clustered around low marks and medium to high marks.

Candidates are encouraged to present their results clearly, using a table if appropriate. Candidates in the lower mark cohort frequently provided very poorly presented results in **Questions 1** and **2**, often in pencil.

In **Question 3**, chemicals labelled **(F)** should not be heated with a flame and candidates should note the instructions in the text that ‘no further chemical tests should be attempted’. When devising tests for anions, candidates should consider that cations present may also react with their selected reagent. An appropriate reagent should be selected.

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

Comments on specific questions

Question 1

(a) Candidates are expected to give precise labels to their experimental data. Some presentation of results was poor, consisting only of numbers with no headings or units. Candidates are encouraged to draw a table for their results. Errors included describing mass as weight and the gas volume as mL rather than cm^3. Most candidates were able to calculate their mass of **FA 1** using appropriate balance readings. A 250 cm^3 measuring cylinder can only measure to a precision of 1 cm^3 and therefore gas volumes should only be quoted to integer values. As an example, 140 cm^3 should not be recorded as 140.0 cm^3. Volumes given in dm^3 to a precision of three decimal places were acceptable. Use of a 1 decimal place balance is only acceptable if lack of a 2 decimal place balance is noted in the supervisor report.

The volume of gas collected should have been approximately 190 cm^3. The collection of much lower volumes was described by some candidates. Centres should be encouraged to practice gas collection experiments for candidates to gain experience of this technique to avoid loss of gas.

(b) (i) The molar volume of gas at room conditions was provided in the paper. The amount, in mol, of carbon dioxide collected can be obtained by dividing the volume collected by this value. Many candidates were able to carry out this calculation to 2 to 4 significant figures correctly. However, some candidates divided their volume collected by 44 (M_r of CO_2) in error.

(ii) Few candidates were able to give the correct equation. Some candidates able to produce the right compounds in the equation did not include the state symbols as requested, for some or all of the species.

(iii) Candidates were expected to use the stoichiometry of the equation from **(b)(ii)** and record that the amount of M_2CO_3 was the same as the amount of CO_2 in **(b)(i)**. Using this value and the candidate's mass of **FA 1**, the M_r of M_2CO_3 could be calculated.

(iv) Candidates with an answer at **(b)(iii)** were able to subtract the relative mass of the carbonate ion (60), divide the answer by two and state **M** as the Group 1 metal with the closest A_r.

(c) This calculation required only the values given in the question and was a straightforward mathematical error calculation. However, only the strongest candidates were able to gain credit. A common error was the use of the errors in equipment which were not relevant to the question.

(d) There were two possible routes to answer this question. Candidates could comment on the use of calcium carbonate (rather than a Group 1 metal carbonate). This would produce calcium sulfate, forming a sparingly soluble layer on the surface, restricting reaction. Insoluble was acceptable as an alternative to sparingly soluble. Alternatively, candidates could comment on the increased particle size, 'small lumps', as the decreased surface area would result in a reaction with a much slower rate. Some good answers were observed.

Question 2

(a) Candidates should have experience of carrying out titrations. There was a clear differential between candidates who had experience of how to set out their results and those that did not. Candidates should record their burette readings for their rough titration and then carry out at least two accurate titrations.

Many candidates did not present their results using clear headings and units. Each burette reading should be clearly labelled. Candidates are encouraged to present their table of results as 'FIT' – final reading/volume, initial reading/volume, titre. Each heading should have correctly displayed units/cm^3, in cm^3 or (cm^3), not mL. As a burette is accurate to 0.05 cm^3, results should be given accordingly – to either #.#5 or #.#0 cm^3. This does not apply to the titre.
The titration should only be repeated until a result is obtained that is within 0.1 cm^3 of another result. Some candidates claimed to have carried out many more titrations than required, which is an unnecessary use of valuable time. Some candidates did not include the titre, this must be shown. In general, the reported titrations were accurate when compared to those of the supervisor.

(b) The values selected to calculate a mean titre should be within 0.2 cm^3. A common error was the selection of results outside this range and occasionally the use of the rough titre, which should not be used.

(c) (i) The calculation was generally carried out well.

(ii) As **Z** is described as a Group 1 metal, the same 1 : 1 stoichiometry of carbonate to acid applies from **1(b)(ii)**. Therefore, the amount of $\mathbf{Z}_2CO_3$ in mol, in 1 dm^3 is 40 × **2(c)(i)**. Some candidates found this challenging and attempted to use 7.26 g from the question stem. As the identity of **Z** had not yet been determined, it was not possible to do so.

(iii) Candidates with an incorrect value in **2(c)(ii)** were able to gain credit by using their value in this question. Using the same process from **1(b)(iv)** most candidates were able to identify metal **Z** from their results. Metal **Z** was required to be a Group 1 metal as stated in the stem. Some candidates incorrectly chose the closest metal (e.g. Zn).

(d) This question was answered poorly in general. Although candidates were able to understand that the concentration of **FA 3** would be lower, the titre decreases because the number of **moles** of $\mathbf{Z}_2CO_3$ are lower. Credit was not awarded if moles were not mentioned.

(e) Vague answers were given comparing the precision of the burette in **Question 2** versus the measuring cylinder in **Question 1**, however these were not the only pieces of equipment used. Balances and pipettes were also used. It is correct to state that the **total** error in equipment in **Question 2** is less than in **Question 1**, but few candidates provided this statement.

Many candidates were able to secure one of the two marks available by noting that some gas would escape before the bung was replaced in **Question 1**. Fewer candidates noted that gas could also be lost as the CO_2 would dissolve in the water. Answers relating to human error or repeating and taking a mean were incorrect.

Question 3

(a) (i) Qualitative analysis notes are provided in the paper for the reactions of cations with NaOH and ammonia. The question states that the ions in **FA 6** and **FA 7** are listed in the Qualitative analysis notes. The answers provided should match those supplied in the notes provided. **FA 6**, containing Fe^{2+} gives a green precipitate, turning brown on contact with air, insoluble in excess with both reagents. The Cr^{3+} ion in **FA 7** gives a grey-green ppt soluble in excess giving a dark green solution with NaOH and a grey-green precipitate, insoluble in excess with ammonia.

It was clear that some candidates were able to identify the cations, but their description of the observations were poor. The precipitates were incorrectly described as ‘cloudy’ or ‘muddy’ which are not appropriate scientific terms. Candidates are provided with examples of observations on page 6.

No candidates saw any change on standing in Test 2. Test 3 was generally not described well. On addition of hydrogen peroxide, the Fe^{2+} will oxidise to Fe^{3+} producing a yellow solution. On addition of NaOH there is vigorous effervescence of oxygen and a brown precipitate is formed. Candidates often did not test the gas and description of the solution and precipitate colour was vague.

Some candidates completed the tests in boxes that were clearly not to be attempted as indicated by the grey shading and a cross through the box.

(ii) The second part of the question required the candidates to design their own tests to identify the anions, which were described as being in the Qualitative notes. The suitable form requested was a table. Some candidates provided clearly set out work and logical tests with the correct results and conclusions. Candidates were mostly able to use barium chloride or nitrate to test for sulfate/sulfite. A common error was to then use potassium manganate(VII) to distinguish between sulfate and sulfite after the observation of a white precipitate with **FA 6**. In **3(a)(i)** the candidates should have identified the cation in **FA 6** as Fe^{2+}. This will oxidise on reaction with potassium manganate(VII) giving a false positive for sulfite and was not an appropriate reagent to use. Some candidates used sulfuric acid to check the solubility of the white precipitate. As a sulfate-containing acid, this is not an appropriate reagent to use.

Many candidates were able to carry out a test with silver nitrate to test for halide ions and observe a white precipitate with **FA 7**. Candidates had already tested **FA 7** with ammonia in **3(a)(i)** and should have concluded that it was not appropriate to test the solubility of the white precipitate formed with ammonia as a grey-green precipitate would be formed, masking any results. Despite this some candidates claimed that the white precipitate dissolved in the ammonia, something they would not be able to observe.

Some candidates wasted time testing for nitrogen containing ions. The question stated that none of the ions contained nitrogen.

(iii) Responses to this question generally depended on the accuracy of the candidate's observations in **3(a)(i)** and the design of tests in **3(a)(ii)**. It was quite common to see $FeSO_3$ rather than the correct $FeSO_4$ for **FA 6** due to inappropriate use of potassium manganate(VII) in **3(a)(ii)**. Candidates observing a cream or off-white precipitate with **FA 7** and silver nitrate could reasonably conclude that **FA 7** was $CrBr_3$ rather than $CrCl_3$ given the highly coloured nature of the solution.

(b) (i) The final qualitative question concerned organic liquid **FA 8**. Some candidates did not read the question and answered **3(b)** in terms of inorganic ions. With potassium manganate(VII) the candidates should have observed the purple potassium manganate(VII) turning colourless due to oxidation of **FA 8** (ethanol, a primary alcohol). Candidates could conclude from this that **FA 8** was either a primary or secondary alcohol or an aldehyde (alcohol alone was insufficient). Some candidates indicated that the functional group was an alkene, however as the question stated that **FA 8** contained only one functional group and C, H and O, this was incorrect.

Candidates could also gain credit by stating that **FA 8** could *not* be a ketone or a tertiary alcohol. Carboxylic acid alone was not an acceptable response as methanoic acid and ethanedioic acid would both decolorise potassium manganate(VII).

(ii) This was a straightforward test where a correct observation was given by almost all the candidates who attempted it. On addition of sodium carbonate to ethanol there is 'no change'. Candidates are reminded that where no change is observed, they should write 'no change' as stated in the instructions. Most candidates, even those who had ignored the fact that **FA 8** was organic, were able to gain credit by stating that **FA 8** was a (carboxylic) acid.

(iii) Candidates found this question challenging, but some were able to provide a test that could distinguish between the functional groups identified in **(b)(i)**. Some candidates provided the observations for this test, rather than the conclusions. For example, the conclusion from a positive Fehling's tests should be that **FA 8** is an aldehyde, not that a brick-red precipitate is formed.

Despite the clear instructions in the paper, some candidates used a Bunsen burner in **3(b)(i)** and some reported attempting a test in **3(b)(iii)**.

CHEMISTRY

Paper 9701/37
Advanced Practical Skills 1

Key messages

Candidates are encouraged to:

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

General comments

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

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

This paper generated a wide range of marks, although few candidates achieved very low or very high marks. A small number of candidates gained full credit in at least one quantitative question. In common with past papers, many candidates found the qualitative analysis question more demanding, though a few gained nearly all the marks available. Almost all candidates were able to complete the paper within the time allowed.

It is important that candidates are acquainted with the information in the initial Quantitative analysis and Qualitative analysis notes given in advance of **Question 1** and **Question 3**. These sections are designed to aid the candidates in their work as are the Qualitative analysis notes given prior to the table of data and Periodic Table at the end of the paper.

Comments on specific questions

Question 1

Candidates generally appeared to be well-prepared in both the practical aspects and the subsequent calculations in this question. However, more attention to the instructions and information given was needed in some parts.

(a) Most candidates seemed well versed in how to present results for a titration question. Column headings were good; however, some candidates used 'initial' rather than 'initial volume'. 'Amount' instead of 'volume' was also seen – candidates should be aware that amount refers to moles. The best heading for the volume added is 'titre'. There were some centres where few candidates recorded their accurate burette readings to the nearest 0.05 cm^3. For most candidates two or three titrations were sufficient to achieve concordant results. Those performing additional titrations run the risk of the final titre being more than 0.10 cm^3 from any other.

(b) Most candidates calculated a mean value. Incorrect rounding and answers given to one decimal place were the usual errors seen.

(c) (i) Many candidates started giving their answers to the expected 3 or 4 significant figures. However, fewer recorded all three answers to the same precision.

(ii) Most candidates answered this correctly. A few did not convert their mean titre to dm^3 or made errors in rounding.

(iii) Many candidates used the stoichiometry given in the question correctly.

(iv) Far fewer candidates calculated the concentration of hydrogen peroxide **FA 1**, possibly owing to insufficient care when reading the question. Many did not include the dilution factor in their calculation so calculated the concentration of hydrogen peroxide in **FA 4** rather than in **FA 1** as instructed.

(d) Very few answered this correctly. Some correctly stated the student's suggestion was incorrect as the acid was in excess. Of those attempting the calculation to show the excess of acid, the inclusion of it being diprotic was usually omitted. Most candidates answered this question in terms of the relative precision of pipettes and measuring cylinders so could not access credit.

Question 2

This question proved challenging for candidates, especially in the section dealing with sources of error and the accuracy of the procedure when one of the variables is changed.

(a) Many candidates gained credit for headings and units for their tables of results. The most common errors were writing C° for the temperature unit and omitting the changes in temperature. Almost all gained credit for clearly linking the volumes of **FA 1** with the associated thermometer readings. Some candidates did not record their thermometer readings to the expected .0 or .5 °C. It was notable that a large minority of candidates did not achieve similar temperature changes for the two experiments. The two ΔT values should be the same within ± 1 °C as the increase in amount of hydrogen peroxide decomposing is compensated by the increase in volume. However, many candidates were able to gain credit for the mean increase in temperature compared with that of the supervisor.

(b) (i) Many candidates calculated the energy change. The most common errors were using $c = 4.2\,kJ\,kg^{-1}\,K^{-1}$, adding 273 to the temperature change for **Experiment 2** or giving the answer to five significant figures. Candidates are expected to use the data supplied in the paper.

(ii) Few candidates gained full credit, although many showed clear working towards the correct answer, usually by the division of **(b)(i)** by 98.2 or 98 200.

(c) (i) In this type of question, candidates should try to relate their answer to the procedure (including the calculation) they have just carried out. It is usual that the amount (number of moles) of substance will be needed as part of the answer. Here, a good starting point is noting a smaller change in temperature is expected owing to heat loss. The calculation in **(b)** linked this to a smaller change in energy, hence a smaller amount of hydrogen peroxide in the volume used and thus a lower concentration. Some candidates worked their way through some of the points but only concluded that the concentration had changed without specifying in which direction. Many candidates did not gain credit as they discussed errors in the use of equipment.

(ii) This was poorly answered. Candidates must indicate explicitly whether or not they agree with the student. There were several valid ways to answer the question: the most commonly awarded answer linked the decrease in ΔT with the increase in its percentage error.

Question 3

A greater knowledge of the introductory information would have benefited many candidates. There should be clarity on whether the product of a reaction is a solid or a solution. The use of correct terminology is expected at this level so, for example, adding a solid to a solution and calling it a precipitate is incorrect.

(a) (i) Very many candidates stated the solution or filtrate turned (dark) green. Very few candidates gave a correct second observation, with ‘red’ or ‘brown’ being common incorrect observations.

(ii) From the observations recorded, it appeared that some candidates did not heat the mixture long enough for sufficient $Fe^{2+}(aq)$ to be formed. Some candidates suggested a gas was evolved or gave the colour of the residue on filtering. The filtrate was often described as green or colourless. Many candidates noted the formation of a brown or red-brown precipitate in the second part but far fewer noted the effect of adding excess aqueous sodium hydroxide.

(iii) The most common incorrect answers were ‘catalyst’ and ‘reducing agent’.

(iv) Few candidates gave a correct ionic equation. Common errors were omission of state symbols and incorrect stoichiometry, especially for the $OH^-(aq)$ ion. Those giving the equation for neutralisation rather than precipitation were generally more successful.

(b) (i) Almost all candidates attempting this part were able to gain at least one mark though very few gained all six. Use of the information given on pages 14 and 15 would have enabled candidates to select colour-descriptions or results of gas tests more likely to gain them credit.

Common errors were:

- ‘orange’ for the precipitate of $Fe(OH)_3(s)$ and/or for $I_2(aq)$
- NH_3 ‘identified’ when warming either or both **FA 6**/**FA 7** with NaOH(aq)
- ‘turns purple’ on adding the reagent $KMnO_4(aq)$ to **FA 6** instead of ‘(solution) remains purple’
- ‘fizzing’ missed in **Test 3** with **FA 7** and (less evident) in **Test 4** with **FA 6**.
- gas tests omitted or incorrectly described.

It is the responsibility of those running the examination at the centres to ensure the reagents are of the correct standard. For example, if $H_2O_2(aq)$ does not bubble on adding a little $MnO_2(s)$ then it is likely to have already decomposed and a fresh supply is needed.

(ii) Candidates should be encouraged to read the instructions carefully as many incorrectly added a second reagent, usually $NH_3(aq)$, after adding the expected $AgNO_3(aq)$. When the solution above the precipitate is coloured, candidates should look at the base of the test-tube to discern the appearance of the less-contaminated part of the precipitate.

(iii) Many candidates were able to identify Fe^{3+} and either or both Cl^- and I^-. Far fewer identified H^+ even when effervescence was recorded on adding $Na_2CO_3(aq)$. A number of candidates also identified K^+ even though there were no tests in the paper for this ion.

CHEMISTRY

Paper 9701/38
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

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

General comments

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

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

This paper generated a wide range of marks, although few candidates achieved very low or very high marks. A small number of candidates gained full credit in at least one quantitative question. In common with past papers, many candidates found the qualitative analysis question more demanding, although a few gained nearly all the marks available. Almost all candidates were able to complete the paper within the time allowed.

It is important that candidates are acquainted with the information in the initial Quantitative analysis and Qualitative analysis notes given in advance of **Question 1** and **Question 3**. These sections are designed to aid the candidates in their work, as are the Qualitative analysis notes given prior to the table of data and Periodic Table at the end of the paper.

Comments on specific questions

Question 1

Candidates generally appeared to be well-prepared in both the practical aspects and the subsequent calculations in this question. However, more attention to the instructions and information given was needed in some parts.

(a) Most candidates seemed well versed in how to present results for a titration question. Column headings were good; however, some candidates used 'initial' rather than 'initial volume'. 'Amount' instead of 'volume' was also seen – candidates should be aware that amount refers to moles. The best heading for the volume added is 'titre'. There were some centres where few candidates recorded their accurate burette readings to the nearest 0.05 cm^3. For most candidates, two or three titrations were sufficient to achieve concordant results. Those performing additional titrations run the risk of the final titre being more than 0.10 cm^3 from any other. Candidates should be reminded that they also need to include burette readings for their rough titre. This can be done either in the space provided or in their results table.

(b) Most candidates obtained the mean value. Incorrect rounding and answers given to one decimal place were the usual errors seen. A small number of candidates did not provide an indication of which titres had been used to calculate the mean.

(c) (i) Most candidates realised that an 'appropriate' number of significant figures meant three or four. However, some candidates rounded their answers to one or two significant figures.

(ii) Most candidates answered this part correctly. Occasionally, a value ending in 5 was rounded down rather than up.

(iii) The majority of candidates correctly used the stoichiometry given in the equation to multiply by 5. However, a much smaller number of candidates then also scaled up by 1000 ÷ 25 to get the correct final answer.

(iv) Candidates generally performed well here, although multiplication by the M_r of hydrated iron(II) sulfate was sometimes seen. Candidates should be reminded to use the data in the Periodic Table provided when answering this type of question.

(v) This was generally done less well than the rest of **(c)**. Candidates should be reminded that the information required to answer this type of question is often found in the information provided at the start of the question. Some candidates misinterpreted what they were being asked to do and stated that their answer was not equal to 150 mg rather than answering the question.

(d) Very few candidates gave a correct suggestion that both acids are strong. A small number of candidates also gave good answers in terms of the proticities of the two acids. Suggestions in terms of the redox chemistry were rare.

Question 2

(a) Candidates generally performed well in **(a)** with most gaining at least three marks. Occasionally, candidates did not record all their thermometer readings to one decimal place ending in 0 or 5. Some candidates selected volumes of **FB 5** greater than 10.00 cm^3 for their additional experiments.

(b) (i) Although there were occasional slips in the labelling of axes and the plotting of points, most candidates were well-prepared in the basics required to draw a graph. Some candidates missed the instruction to allow for a temperature 2 °C greater than their largest maximum temperature. Candidates fared least well with their lines of best fit. Candidates should be reminded that all their points should either be included when drawing their lines of best fit or they should be labelled as anomalous.

(ii) Nearly all the candidates who had an intersection on their graph correctly read off the volume on the *x*-axis.

(c) (i) Most candidates calculated this correctly, although sometimes the amount of sodium hydroxide was given as either double or half the amount of hydrochloric acid.

(ii) Although the expression for working out the energy change was known to most candidates, only a small proportion obtained a correct answer. By far the most common error was not realising that the total volume used in each experiment was 20.00 cm^3.

(iii) The method for working out the enthalpy change from the energy released and the number of moles was familiar to most candidates. Very few candidates made a mistake with the sign of the enthalpy change. Occasionally candidates did not convert their energy change to kJ.

Question 3

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

(a) (i) Most candidates recorded effervescence for the appropriate tests, noted ‘no change’ when required and observed the green precipitate with **FB 7** in **Test 3**. Better performing candidates also recorded correct gas tests and noted the green precipitate turning brown on contact with air.

(ii) This question proved difficult for most candidates and many were unable to deduce much from their observations. The correct identities of **FB 6** (possibly from the smell) and **FB 7** were seen more frequently than **FB 8**.

(b) (i) As was the case in **(a)(i)**, most candidates reported the fizzing but far fewer went on to try and test the gas produced. Amongst those who did test for carbon dioxide, many candidates reported the limewater going cloudy or milky rather than producing a white precipitate. The correct test for carbon dioxide is clearly stated in the Qualitative analysis notes.

(ii) Candidates performed reasonably well here although some did not perform the second part of the test. It is worth noting that for the halide test, candidates should decide whether the precipitate is white, cream or pale yellow. Answers such as cream-white or creamy white are not credited.

(iii) Occasionally, in **Test 1**, candidates did not write ‘no change’ in the top box. Regarding the second box, candidates should be reminded that when doing the test for ammonia, they should make it clear that they are testing the gas produced and not the solution. Candidates performed well on **Test 2**, with most recording one of the accepted colours for the final solution.

(iv) The conclusions here were generally more accurate than in **(a)(ii)**. Candidates should take care when writing formulas that the use of subscript (for numbers) and superscript (for charges) is accurate. Some candidates were not awarded credit here by guessing the identity of one of the cations when there was no test for it and so ‘unknown’ should have been recorded.

(v) A correct ionic equation with state symbols was only given by a minority of candidates. State symbols were often missing or incorrect.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- Candidates are advised to take care when writing words that could be read in more than one way – for example, exothermic or endothermic. This also happens with numbers; 1 and 2 can be written in a similar way, as can 4 and 9. Responses must be written in a legible way and be unambiguous.
- If a candidate wishes to change an answer, the original answer must be crossed out completely. If there is insufficient space to write the replacement answer in the answer space, there is plenty of blank space on the question paper. Any response that is not written in the given response space must be clearly labelled, such as ‘see page 2’.
- Answers to calculations should be given to a minimum of 2 significant figures but 3 significant figures 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 significant figures.
- Every step in a candidate’s calculation should be clearly explained.

General comments

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

When the name of an organic substance is asked for, care must be taken to apply the accepted rules.

The majority of candidates were able to work through to the end of the paper, giving a reasonable answer for **Question 10(c)**.

Some loose descriptions rather than precise language were seen. The word ‘it’ should be avoided wherever possible, for example when comparing the enthalpy changes of hydration of K^+ and Ca^{2+}. In organic chemistry, the expression ‘the bond’ is vague – there are many bonds in most organic molecules. An expression such as ‘the C–Cl bond’ or ‘the O–H’ bond should always be used, for example, in **Question 8(b)(ii)** and **Question 10(c)**.

When a comparison of bonding or attractive forces are required to answer a question, simple and plain words such as ‘stronger’ and ‘weaker’ should be used. Descriptions such as ‘it is easier for Ca^{2+} to attract water molecules than it is for K^+ to attract water molecules’ will not gain credit. By comparison, ‘Ca^{2+} ions attract water molecules more strongly than K^+ ions attract water molecules’ will gain credit.

Many candidates showed the skills needed to answer an examination paper of this type. Areas where improvement was apparent included:

- 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 e.g., the shape of the octahedral complex.
- the observations that can be made during practical work, for example **Question 10(b)**.

Comments on specific questions

Question 1

(a) This was answered well.

(b) This discriminated well. Although many good answers were seen, weaker answers focused on the strength of the ionic bonds between M^{2+} ions and CO_3^{2-} ions, rather than the polarisation of the CO_3^{2-} ions.

(c) (i) This was answered well.

(ii) This question attempted to put familiar material – the solubility of the Group 2 hydroxides – into a slightly different context. The accurate use of terms such as 'more exothermic' was seen in many responses.

Question 2

(a) (i) This was answered well by many candidates. A small number of candidates submitted unfinished answers, such as $\text{mol dm}^{-3}\text{ s}^{-1} / (\text{mol dm}^{-3})^3$. These did not gain credit.

(ii) This was answered well by many candidates. However, many calculations reached 4.60×10^{-3}, but then continued making one further and unnecessary step.

(iii) This was answered well, although many long and complicated methods were seen. Since the initial concentrations of both reactants are ten times greater than in experiment 1, the rate of the reaction in experiment 2 is one thousand times the rate in experiment 1.

(b) (i) This discriminated well. Many answers stated 'the reaction is first order with respect to chlorine.' This is correct but was not enough for credit. It was also important to state that since NO is in large excess its concentration is effectively unchanging.

(ii) No credit was awarded for answers that quoted $105.6 = \ln 2/t_{½}$ but went no further. If the candidate rearranged this expression, giving $t_{½} = \ln 2/105.6$, which does evaluate to 6.56×10^{-3}, credit was awarded.

(iii) This discriminated well. Many candidates could reduce the number of half-life periods that had elapsed and then work through to the correct answer.

(c) Many candidates found this difficult. Most stated that NO is a catalyst but only a minority were able to explain this by pointing out that NO is regenerated in the reactions that occur. A significant number of equations were seen involving incorrect or uninvolved species such as SO, N and N_2.

Question 3

(a) (i) This discriminated well. Some candidates incorrectly included $[Cr(OH)_3]$ in their K_{sp} expression.

(ii) This was answered well by many candidates. Mistakes seen included:

- not appreciating that if $[Cr^{3+}] = x$ then $[OH^-] = 3x$.
- missing the instruction to give the solubility in g dm^{-3}, not mol dm^{-3}.

(iii) This was answered well.

(b) (i) Most candidates answered this well. Where there were errors, they often originated in an attempt to use the Henderson-Hasselbalch equation. Candidates who used the K_a expression had much more success.

(ii) This was answered well.

(iii) This was found to be very difficult. Many candidates did not appreciate that the NaOH added will react with the $CH_3CH_2CH_2COOH$ to produce some $CH_3CH_2CH_2COONa$. Better performing candidates explained their calculations in each step. For example:

- moles of $CH_3CH_2CH_2COOH$ before adding NaOH =
- moles of $CH_3CH_2CH_2COOH$ after adding NaOH =
- moles of $CH_3CH_2CH_2COO^-Na^+$ before adding NaOH =
- moles of $CH_3CH_2CH_2COO^-Na^+$ after adding NaOH =

(c) Most candidates answered this well. As a first step, it was important for candidates to state that 0.148 g of $CH_3CH_2CH_2COOH$ is still dissolved in the aqueous layer.

Question 4

(a) (i) This was answered well. Some candidates did not gain credit because their definition began ‘Energy needed’ or ‘Energy required’. This implies the value is positive, which it is not.

(ii) Many candidates did not give a clear explanation. The difference is due to the difference in both ionic charge and ionic radius. The forces of attraction involved are due to different ion-dipole forces with water molecules, not different chemical bonds with water molecules.

(iii) This was answered well by the majority of candidates. Better responses used ‘from gaseous ions’ in their definition rather than ‘from the elements in their gaseous ion states’. For some ionic compounds, such as $CaCO_3$, one of the ions cannot be considered as an element in its gaseous ion state.

(iv) This was answered well. Commonly seen errors were sign errors, failing to appreciate there are two fluoride ions in each formula unit of CaF_2 and, more rarely, using data for K^+.

(b) This was answered well. Commonly seen errors were use of 25 °C in place of 298 K and not converting a first answer of $0.1745\ kJ\ K^{-1}\ mol^{-1}$ to $174.5\ J\ K^{-1}\ mol^{-1}$.

Question 5

(a) (i) This discriminated well. Many candidates included an occupied 4 s orbital.

(ii) This discriminated well.

(b) (i) This discriminated well.

(ii) Correct answers were rare. Many unbalanced equations were seen, as were equations with incorrect products such as $[Cu(NH_3)_2(H_2O)_4]^{2+}$.

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

(ii) This discriminated well. Unbalanced equations were often seen, as were equations with incorrect products such as $[Cu(NH_3)_6]^{2+}$.

(iii) This was answered well.

(d) (i) This was answered much better than questions about the Nernst equation in previous sessions. Some candidates used E_{cell} not E° and so did not gain full credit.

(ii) This discriminated well. 1.18 V was a commonly seen answer.

(iii) This was answered well. The commonest error was:
$5Cu^{2+} + 2MnO_4^- + 16H^+ \rightarrow 5Cu + 2Mn^{2+} + 8H_2O$.

(iv) This was answered well. In questions about electrochemical cells, it is advisable to avoid use of ‘anode’ and ‘cathode’. In this case, that meant using Cu^{2+}/Cu and MnO_4^- instead.

(e) This discriminated well. Better performing candidates gave a clear explanation of the necessary working. Many candidates who did not get the correct answer were still able to gain some credit for this working out.

Question 6

(a) (i) This was answered well.

(ii) This required care. Loose expressions like 'different energy gap' did not gain credit; 'different gap between split d orbitals' did gain credit. Most candidates stated that a different frequency (or wavelength) of light is absorbed.

(iii) This was answered very well.

(b) This was highly discriminating. Some excellent answers were seen. Common errors included:

- poor use of three-dimensional bonds in the diagrams
- ignoring the instruction to include one bond angle
- poor depiction of an arc to specify which bond the angle relates to
- ignoring the information in the question about CN^- ligands or CO ligands.

A significant number of scripts showed the bonding of the silver complex as $H_3N=Ag=NH_3$. This is very unusual and impossible as the nitrogen atoms cannot form two double bonds while remaining bonded to three hydrogen atoms.

It should also be noted that three-dimensional bonds are not needed to show the silver and palladium complexes. This is the reason for the words 'where necessary' in the question.

Question 7

(a) This was answered well. Common errors were 1,2-diethyl benzene and 1,3-dimethylbenzene.

(b) (i) This was answered well. $CdCl_3$ was an often seen wrong answer.

(ii) Candidates who knew there is no difference usually went on to give a correct explanation.

(iii) This discriminated well.

- The number of ^1H atoms responsible for the peak, was rarely given. Many candidates gave the number of neighbouring protons responsible for the splitting pattern.
- The group responsible for the peak, was identified by under 50% of candidates. A common wrong answer was CH_2–Ar for the peak at d = 2.7. Since the aryl ring also has four protons this answer is ambiguous.
- The splitting pattern was usually given correctly.

(iv) This discriminated well.

(c) (i) This discriminated well. Many candidates missed the instruction to use molecular formulae.

(ii) This discriminated well. The structure of **G** was found easiest, the structure of **K** was found hardest.

Question 8

(a) (i) This was answered well.

(ii) Many candidates ignored or did not appreciate the reference to the reaction being in the dark. This usually resulted in a discussion of $C_6H_5CH_2Br$, rather than 3-bromomethylbenzene.

(iii) This question about the mechanism of electrophilic addition was answered well. Many candidates took care to show the structure of the intermediate correctly.

(b) (i) This discriminated well.

(ii) These equations were found very difficult. Credit was given for $Ag^+ + Cl^- \rightarrow AgCl$ to many candidates, but the equation $C_4H_9Cl + H_2O \rightarrow C_4H_9OH + HCl$ was rarely awarded. Many equations were seen in which the nitrate ion played a significant part; is a spectator ion here.

(iii) Better performing candidates used correct vocabulary in the correct places. For example, 'in chlorobenzene the lone pair on the chlorine atom is delocalised into the benzene ring, this causes a strengthening of the C–Cl bond.' This makes it clear:

- which substance is being referred to
- what happens to the lone pair
- where the lone pair is delocalised into
- which bond is strengthened.

Question 9

(a) (i) This discriminated well. $C_6H_5CONH_2$ was a commonly seen wrong organic compound. Tin was sometimes incorrectly described as a catalyst.

(ii) This discriminated well. $CH_3CH_2CH_2CN$ was a commonly seen wrong organic compound.

(iii) This discriminated well. Many candidates chose HNO_2 as testing reagent, but this will not produce a white precipitate in a single test

(b) Many excellent answers were seen, using the correct vocabulary specifically and in the relevant places.

Question 10

(a) This was answered well.

(b) Although some excellent answers were seen, this material was not well known. Attention should be drawn to the observations during the reaction of acidified $KMnO_4$ with methanoic acid or ethanedioic acid. Although CO_2 is a product of this reaction, 'effervescence' is not a good description of the possible observations. At the concentrations that may be used, very little identifiable bubbling will be seen. The decolourisation of the acidified $KMnO_4$ is much more obvious.

(c) This was answered well, often by using the correct vocabulary specifically and in the relevant places.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Answers to calculations should be given to a minimum of 2 significant figures but 3 significant figures 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 significant figures.
- 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 and a comment noting the location of the answer should be added.

General comments

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

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

Working should be shown when answering questions involving calculation.

Comments on specific questions

Question 1

(a) (i) Most candidates gave the correct equation for the decomposition of calcium nitrate. Common errors included incorrect balancing, O_2 as a reactant and Ca and NO as products.

(ii) Most candidates had prepared well for this question. Many gave a correct statement regarding increasing decomposition temperature and increasing cation radius down Group 2. Some omitted any reference to the decomposition temperature and just mentioned thermal stability increases, which was not sufficient. Decreasing polarisation of the nitrate anion was less frequently seen. Some candidates incorrectly suggested there was polarisation of the cation or that polarisation was caused by the anion. A few incorrectly discussed the strength of the ionic bond increases between anion and cation, rather than the N–O bond becoming stronger.

(b) Many candidates produced completely correct calculations with well-structured working. A common error was 12.4; candidates had to give their answer to two decimal places. Other common errors included:

- 12.11: no ×2 in finding the moles of OH^-
- 12.34 and 12.35: incorrect M_r used 121.6 and 119.6 respectively
- 11.81: no ×4 in finding the moles of OH^- in 1 dm^3.

Question 2

(a) (i) Some excellent answers were seen. The formulae resulted in the most errors such as $[Co(H_2O)_4(OH)_2]^{2+}$ instead of $[Co(H_2O)_4(OH)_2]$, and $[Co(NH_3)_4(H_2O)_2]^{2+}$ instead of $[Co(NH_3)_6]^{2+}$. The colours for **A** and **B** were well known. Yellow was a common error for **C**. The types of reaction were normally correct.

(ii) This was not well known and proved difficult for candidates. 'Concentrated' was often omitted with HCl and another common error was $NaCl$.

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

(ii) Many accurately drawn correct answers were seen, using correct conventions for the three-dimensional bonds of wedged and dashed bonds.

(c) This question discriminated well. Many candidates were able to identify a reaction for H_2O_2 to act as an oxidising agent and another to act as a reducing agent. Common errors included writing unbalanced equations and not cancelling the same species on both sides of the equation. In addition, some gave equations that did not have H_2O_2 as a reactant, which gained no credit.

(d) (i) This was not well known and proved difficult for candidates. Many candidates thought the colour changed from purple to colourless at the end point of the titration, or vice versa.

(ii) Many good answers were seen. Common errors included:

- 31.1 mg: not multiplying the moles of MnO_4^- by five
- 130 mg: not multiplying the moles of MnO_4^- by six
- 0.778 mg: not converting grams to milligrams by multiplying by 1000
- 1560 mg: not dividing the final mass by two to find mass of one tablet.

Question 3

(a) This definition was well known. Some incorrectly used the term randomness for disorder, while others did not include 'system' in their answers.

(b) (i) Most candidates were able to correctly identify the changes of state occurring at T_1 and T_2. Evaporation was not accepted for the process at T_2.

(ii) This proved difficult for many candidates. Many did not compare the entropy change occurring at T_1 with T_2 and only compared the entropy change between liquid and gas.

(c) This was usually answered well, with a good understanding of energy cycles and correct application of the Gibbs equation. It is important to emphasise the value of showing clear working. Candidates who were unable to calculate the correct answer normally gained partial credit from calculating ΔH and using the Gibbs' equation with the T = 723 K. Common errors included +592.8 (no division by 3) and +174.7 (error carried forward using ΔH = +24.8). Other errors were using 273 K or 298 K in their calculation (rather than 723 K) or not multiplying by 1000 to find ΔS in $J K^{-1} mol^{-1}$.

(d) This question was answered well by many candidates. Just stating that the reaction would become less feasible due to ΔG becoming more endothermic/increasing was not accepted. Candidates had to relate the effect of increasing temperature on $-T\Delta S$ and ΔG becoming less negative or more positive.

Question 4

(a) (i) This proved difficult for candidates. Responses often lacked precision, missing some of the key components for this definition.

(ii) Most candidates gave the correct answer.

(iii) This was generally well answered. As the reaction is first order with respect to $[I^-]$, a curve with a negative gradient was expected. Some candidates confused their answer with the rate-against-concentration curve and thus gave a straight line with positive gradient.

(b) (i) Most candidates gave a correct answer. A common error seen was 8 times.

(ii) This definition was well known.

(iii) This was generally well answered and many candidates gained full credit. Common errors included writing equations that were not consistent with the order of reaction for NO_2 and O_3. Candidates should remember that their steps should be unimolecular or bimolecular since collisions involving more than two particles are highly improbable.

(c) (i) This answer was usually correct. The most common error was $k = 300$.

(ii) Many candidates were able to calculate the half-life correctly, according to the formula $t_{1/2} = 0.693 / k$.

Question 5

(a) (i) This was usually answered well, with a good understanding of the conjugate acid-base pairs. H_3O^+ was a common error for acid II.

(ii) Most candidates correctly this calculated.

(iii) This question discriminated well. The most common error was using $HClO_5$ or $HClO_2$ for the formula for chloric(V) acid, instead of $HClO_3$.

(b) (i) This definition was well known. However, some did not give a precise definition, stating that the pH would remain constant or omitting ‘small’ amounts. Adding ‘moderate’ amounts of acid and base was not credited.

(ii) Many candidates were able to suggest NaOH or sodium ethanoate as the substance to be added. However, some found it difficult to explain why either of these substances would make the final solution act as a buffer.

(c) Candidates found this question challenging. It was common to see $H_2PO_4^- + H^+ \rightarrow H_3PO_4$. It was rarer to see $H_2PO_4^-$ react with OH^-. Many gave an incorrect formula for HPO_4^{2-} as HPO_4^-.

(d) (i) Candidates performed well on this question. A common error was 1.93×10^{-35} (no × 17 and × 4 used). The units were normally correct.

(ii) This was generally well answered. Some candidates omitted a comment for the effect on the solubility or just explained that there was a common ion effect.

Question 6

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

(ii) Those who had learnt the electrophilic substitution mechanism found this to be accessible.

Common errors included:

- the curly arrow from the benzene ring did not go to the N of $^+NO_2$
- an incorrect structure of the intermediate – the partly delocalised ring should not include the sp^3 carbon, and the positive charge should not be on the sp^3 carbon
- the curly arrow in the intermediate starting on the H not on the C-H bond
- the additional product given as H or $\frac{1}{2}H_2$ instead of H^+ at the end of the mechanism.

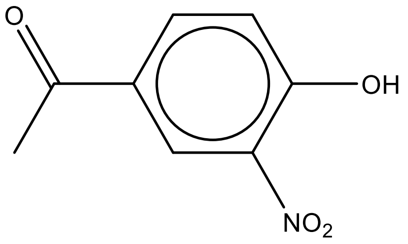
(b) Candidates performed well on this question. Most candidates recognised that the lone pair on the O of OH is delocalised into the benzene ring. The explanation to the effect on the electron density of the ring which leads to the electrophile being polarised more was sometimes omitted. Some candidates explained in terms of increased charge density which was not sufficient.

(c) The equation was frequently incorrect. It was common to see H^+ as a product instead of H_2.

(d) (i) Candidates performed well on this question. Common errors included referring to tin as a catalyst, or omitting that hydrochloric acid should be concentrated. Some gave the reducing agent as $LiAlH_4$ which gained no credit.

(ii) This answer was usually correct.

(iii) Many correct structures were seen. A common error was the product from the acylation of the ring.



(iv) This was generally well answered. Condensation and esterification were insufficient to describe this mechanism.

(e) This was well understood. Sometimes the order of relative acidities was incorrect, and some answers lacked precision or gave insufficient detail. Many candidates could link acidity to weakening the O−H bond and the ability of a proton to be donated. In addition, many recognised that the lone pair on the O of OH is delocalised into the benzene ring, weakening the O–H bond. However, the importance of electron donating groups, such as C_2H_5 in ethanol, and electron withdrawing groups, such as the NO_2 group in 2-nitrophenol, to the strength of the O–H bond was not appreciated by all candidates.

(f) (i) Many candidates found this question challenging. Most candidates could identify the amine and alcohol groups but seemed unfamiliar with use of the term classification in relation to these functional groups. It is worth noting that alkane or alkyl is not considered as a functional group.

(ii) Correct structures were often seen. A common error was to substitute the Br into the 3 or 5 positions of the benzene ring, and/or substituting the –OH group with Br in the side chain.

(iii) Many candidates did not realise that $SOCl_2$ only substituted the alcohol groups of salbutamol and replaced the phenolic OH.

Question 7

(a) This definition was generally well answered. Common errors included:

- stating mirror images were ‘superimposable’
- omitting ‘rotate’ or ‘plane’ in their definition.

(b) (i) Many candidates found this challenging. Some good answers were seen. Candidates had to describe that the lone pair on N accepts a proton from water to produce OH^- ions (thus the aqueous solution being >7) and include a relevant equation.

(ii) This proved difficult for candidates. Often answers were too vague, just stating alkyl groups are electron donating groups. Candidates needed to explain why an aqueous solution of diethylamine had a higher pH than 2–aminobutane. The explanation needed to be in terms of the two alkyl groups attached to the nitrogen, which increases the electron density on the nitrogen, so the lone pair is more available to accept a proton.

(iii) This proved difficult for many candidates and they did not realise that this was an acid-base reaction. A common error was forming the amide, $CH_3CON(CH_2CH_3)_2$, and water as the products.

(iv) Candidates answered this question well. The most common error was giving the incorrect formula of the amide product as $CH_3CONH(CH_2CH_3)_2$.

(c) (i) This was answered correctly by most candidates.

(ii) Many fully correct repeat units were seen. Common errors included:

- not displaying the amide link
- drawing more than one repeat unit
- not putting Hs on all the carbon atoms in displayed structures
- putting the O in the chain e.g. −N−O−C−, and
- not showing continuation bonds on both sides of the repeat unit.

(iii) This question was answered correctly by most candidates. A common error was stating that the C=C bond needed to be broken.

Question 8

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

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

(c) Many good answers were seen for this question. Candidates were more successful in identifying the splitting patterns and the number of protons on the adjacent carbon atoms. The number of ^1H atoms responsible for each peak was found more challenging and normally did not equal twelve in total. It is worth noting that some variant spellings seen in the ‘splitting pattern’ column, including duplet, quatret, quardret, quadlet, were not awarded credit. Some candidates incorrectly identified the chemical shift at 2.85 as the $\text{-C}\mathbf{H}(CH_3)_2$.

Question 9

(a) Many good answers were seen for this question. Common errors were inclusion of a trivalent carbon or drawing a section of a polymer with continuation bonds instead of a dipeptide. Since a dipeptide was asked for, the terminal groups should have been $–NH_2$ and –COOH.

(b) (i) Many correct responses were seen for this question. Some candidates omitted pH in their description and did not gain credit.

(ii) This was generally answered well. The most common error was to state that lys and ser-lys go towards the positive electrode. The explanation needed to be in terms of charge of species ‘for the direction’ and size of particles ‘for distance moved towards the electrode’.

(c) (i) Many incorrect structures were seen because candidates did not realise that step 1 was the acid hydrolysis of an amide group.

(ii) Many candidates found this question challenging since they did not understand that step 1 was an acid hydrolysis and step 2 was an esterification reaction. Those who did realise that step 2 was esterification often did not give the correct conditions.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates are advised to take care when writing words that could be read in more than one way – for example, exothermic or endothermic. This also happens with numbers; 1 and 2 can be written in a similar way, as can 4 and 9. Responses must be written in a legible way and be unambiguous.
- If a candidate wishes to change an answer, the original answer must be crossed out completely. If there is insufficient space to write the replacement answer in the answer space, there is plenty of blank space on the question paper. Any response that is not written in the given response space must be clearly labelled, such as ‘see page 2’.
- Answers to calculations should be given to a minimum of 2 significant figures but 3 significant figures 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 significant figures.
- Every step in a candidate’s calculation should be clearly explained.

General comments

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

When the name of an organic substance is asked for, care must be taken to apply the accepted rules.

The majority of candidates were able to work through to the end of the paper, giving a reasonable answer for **Question 10(c)**.

Some loose descriptions rather than precise language were seen. The word ‘it’ should be avoided wherever possible, for example when comparing the enthalpy changes of hydration of K^+ and Ca^{2+}. In organic chemistry, the expression ‘the bond’ is vague – there are many bonds in most organic molecules. An expression such as ‘the C–C*l* bond’ or ‘the O–H’ bond should always be used, for example, in **Question 8(b)(ii)** and **Question 10(c)**.

When a comparison of bonding or attractive forces are required to answer a question, simple and plain words such as ‘stronger’ and ‘weaker’ should be used. Descriptions such as ‘it is easier for Ca^{2+} to attract water molecules than it is for K^+ to attract water molecules’ will not gain credit. By comparison, ‘Ca^{2+} ions attract water molecules more strongly than K^+ ions attract water molecules’ will gain credit.

Many candidates showed the skills needed to answer an examination paper of this type. Areas where improvement was apparent included:

- 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 e.g., the shape of the octahedral complex.
- the observations that can be made during practical work, for example **Question 10(b)**.

Comments on specific questions

Question 1

(a) This was answered well.

(b) This discriminated well. Although many good answers were seen, weaker answers focused on the strength of the ionic bonds between M^{2+} ions and CO_3^{2-} ions, rather than the polarisation of the CO_3^{2-} ions.

(c) (i) This was answered well.

(ii) This question attempted to put familiar material – the solubility of the Group 2 hydroxides – into a slightly different context. The accurate use of terms such as 'more exothermic' was seen in many responses.

Question 2

(a) (i) This was answered well by many candidates. A small number of candidates submitted unfinished answers, such as $mol\ dm^{-3}\ s^{-1} / (mol\ dm^{-3})^3$. These did not gain credit.

(ii) This was answered well by many candidates. However, many calculations reached 4.60×10^{-3}, but then continued making one further and unnecessary step.

(iii) This was answered well, although many long and complicated methods were seen. Since the initial concentrations of both reactants are ten times greater than in experiment 1, the rate of the reaction in experiment 2 is one thousand times the rate in experiment 1.

(b) (i) This discriminated well. Many answers stated 'the reaction is first order with respect to chlorine.' This is correct but was not enough for credit. It was also important to state that since NO is in large excess its concentration is effectively unchanging.

(ii) No credit was awarded for answers that quoted $105.6 = \ln 2/t_{½}$ but went no further. If the candidate rearranged this expression, giving $t_{½} = \ln 2/105.6$, which does evaluate to 6.56×10^{-3}, credit was awarded.

(iii) This discriminated well. Many candidates could reduce the number of half-life periods that had elapsed and then work through to the correct answer.

(c) Many candidates found this difficult. Most stated that NO is a catalyst but only a minority were able to explain this by pointing out that NO is regenerated in the reactions that occur. A significant number of equations were seen involving incorrect or uninvolved species such as SO, N and N_2.

Question 3

(a) (i) This discriminated well. Some candidates incorrectly included $[Cr(OH)_3]$ in their K_{sp} expression.

(ii) This was answered well by many candidates. Mistakes seen included:

- not appreciating that if $[Cr^{3+}] = x$ then $[OH^-] = 3x$.
- missing the instruction to give the solubility in $g\ dm^{-3}$, not $mol\ dm^{-3}$.

(iii) This was answered well.

(b) (i) Most candidates answered this well. Where there were errors, they often originated in an attempt to use the Henderson-Hasselbalch equation. Candidates who used the K_a expression had much more success.

(ii) This was answered well.

(iii) This was found to be very difficult. Many candidates did not appreciate that the NaOH added will react with the $CH_3CH_2CH_2COOH$ to produce some $CH_3CH_2CH_2COONa$. Better performing candidates explained their calculations in each step. For example:

- moles of $CH_3CH_2CH_2COOH$ before adding NaOH =
- moles of $CH_3CH_2CH_2COOH$ after adding NaOH =
- moles of $CH_3CH_2CH_2COO^-Na^+$ before adding NaOH =
- moles of $CH_3CH_2CH_2COO^-Na^+$ after adding NaOH =

(c) Most candidates answered this well. As a first step, it was important for candidates to state that 0.148 g of $CH_3CH_2CH_2COOH$ is still dissolved in the aqueous layer.

Question 4

(a) (i) This was answered well. Some candidates did not gain credit because their definition began 'Energy needed' or 'Energy required'. This implies the value is positive, which it is not.

(ii) Many candidates did not give a clear explanation. The difference is due to the difference in both ionic charge and ionic radius. The forces of attraction involved are due to different ion-dipole forces with water molecules, not different chemical bonds with water molecules.

(iii) This was answered well by the majority of candidates. Better responses used 'from gaseous ions' in their definition rather than 'from the elements in their gaseous ion states'. For some ionic compounds, such as $CaCO_3$, one of the ions cannot be considered as an element in its gaseous ion state.

(iv) This was answered well. Commonly seen errors were sign errors, failing to appreciate there are two fluoride ions in each formula unit of CaF_2 and, more rarely, using data for K^+.

(b) This was answered well. Commonly seen errors were use of 25 °C in place of 298 K and not converting a first answer of 0.1745 $kJ\,K^{-1}\,mol^{-1}$ to 174.5 $J\,K^{-1}\,mol^{-1}$.

Question 5

(a) (i) This discriminated well. Many candidates included an occupied 4 s orbital.

(ii) This discriminated well.

(b) (i) This discriminated well.

(ii) Correct answers were rare. Many unbalanced equations were seen, as were equations with incorrect products such as $[Cu(NH_3)_2(H_2O)_4]^{2+}$.

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

(ii) This discriminated well. Unbalanced equations were often seen, as were equations with incorrect products such as $[Cu(NH_3)_6]^{2+}$.

(iii) This was answered well.

(d) (i) This was answered much better than questions about the Nernst equation in previous sessions. Some candidates used E_{cell} not E^{o} and so did not gain full credit.

(ii) This discriminated well. 1.18 V was a commonly seen answer.

(iii) This was answered well. The commonest error was:
$5Cu^{2+} + 2MnO_4^- + 16H^+ \rightarrow 5Cu + 2Mn^{2+} + 8H_2O$.

(iv) This was answered well. In questions about electrochemical cells, it is advisable to avoid use of 'anode' and 'cathode'. In this case, that meant using Cu^{2+}/Cu and MnO_4^- instead.

(e) This discriminated well. Better performing candidates gave a clear explanation of the necessary working. Many candidates who did not get the correct answer were still able to gain some credit for this working out.

Question 6

(a) (i) This was answered well.

(ii) This required care. Loose expressions like 'different energy gap' did not gain credit; 'different gap between split d orbitals' did gain credit. Most candidates stated that a different frequency (or wavelength) of light is absorbed.

(iii) This was answered very well.

(b) This was highly discriminating. Some excellent answers were seen. Common errors included:

- poor use of three-dimensional bonds in the diagrams
- ignoring the instruction to include one bond angle
- poor depiction of an arc to specify which bond the angle relates to
- ignoring the information in the question about CN^- ligands or CO ligands.

A significant number of scripts showed the bonding of the silver complex as $H_3N{=}Ag{=}NH_3$. This is very unusual and impossible as the nitrogen atoms cannot form two double bonds while remaining bonded to three hydrogen atoms.

It should also be noted that three-dimensional bonds are not needed to show the silver and palladium complexes. This is the reason for the words 'where necessary' in the question.

Question 7

(a) This was answered well. Common errors were 1,2-diethyl benzene and 1,3-dimethylbenzene.

(b) (i) This was answered well. $CdCl_3$ was an often seen wrong answer.

(ii) Candidates who knew there is no difference usually went on to give a correct explanation.

(iii) This discriminated well.

- The number of ^1H atoms responsible for the peak, was rarely given. Many candidates gave the number of neighbouring protons responsible for the splitting pattern.
- The group responsible for the peak, was identified by under 50% of candidates. A common wrong answer was CH_2–Ar for the peak at d = 2.7. Since the aryl ring also has four protons this answer is ambiguous.
- The splitting pattern was usually given correctly.

(iv) This discriminated well.

(c) (i) This discriminated well. Many candidates missed the instruction to use molecular formulae.

(ii) This discriminated well. The structure of **G** was found easiest, the structure of **K** was found hardest.

Question 8

(a) (i) This was answered well.

(ii) Many candidates ignored or did not appreciate the reference to the reaction being in the dark. This usually resulted in a discussion of $C_6H_5CH_2Br$, rather than 3-bromomethylbenzene.

(iii) This question about the mechanism of electrophilic addition was answered well. Many candidates took care to show the structure of the intermediate correctly.

(b) (i) This discriminated well.

(ii) These equations were found very difficult. Credit was given for $Ag^+ + Cl^- \rightarrow AgCl$ to many candidates, but the equation $C_4H_9Cl + H_2O \rightarrow C_4H_9OH + HCl$ was rarely awarded. Many equations were seen in which the nitrate ion played a significant part; is a spectator ion here.

(iii) Better performing candidates used correct vocabulary in the correct places. For example, 'in chlorobenzene the lone pair on the chlorine atom is delocalised into the benzene ring, this causes a strengthening of the C–Cl bond.' This makes it clear:

- which substance is being referred to
- what happens to the lone pair
- where the lone pair is delocalised into
- which bond is strengthened.

Question 9

(a) (i) This discriminated well. $C_6H_5CONH_2$ was a commonly seen wrong organic compound. Tin was sometimes incorrectly described as a catalyst.

(ii) This discriminated well. $CH_3CH_2CH_2CN$ was a commonly seen wrong organic compound.

(iii) This discriminated well. Many candidates chose HNO_2 as testing reagent, but this will not produce a white precipitate in a single test

(b) Many excellent answers were seen, using the correct vocabulary specifically and in the relevant places.

Question 10

(a) This was answered well.

(b) Although some excellent answers were seen, this material was not well known. Attention should be drawn to the observations during the reaction of acidified $KMnO_4$ with methanoic acid or ethanedioic acid. Although CO_2 is a product of this reaction, 'effervescence' is not a good description of the possible observations. At the concentrations that may be used, very little identifiable bubbling will be seen. The decolourisation of the acidified $KMnO_4$ is much more obvious.

(c) This was answered well, often by using the correct vocabulary specifically and in the relevant places.

CHEMISTRY

Paper 9701/44
A Level Structured Questions

Key messages

- Candidates must read questions carefully and be sure of what is being asked before beginning their answers. Some candidates wrote good chemistry which was not creditworthy because it did not address the question being asked.
- It was clear that past-papers had been used extensively for preparation by the cohort. Candidates who performed less well gave stock answers to questions that looked similar to those they had practiced on.
- Candidate handwriting for this paper was generally very good. Poor handwriting that results in ambiguous spellings of key terminology or chemical names is unlikely to gain credit.
- Calculations were generally clearly set out. Better performing candidates included labelling of each step.
- Candidates should understand that incorrect language or grammar in their answers can lead to different meanings. For example, 'resistant to pH change on addition *of* a small amount of acid or base' is different to 'resistant to pH change on addition *to* a small amount of acid or base'.
- Candidates must not overwrite incorrect work. Incorrect work should be neatly crossed out and the new answer given in the available space.
- When determining structures, candidates must ensure they match all the criteria given, which may include the formula and/or functional groups present.
- Three-dimensional structures must be drawn correctly. If this is not done correctly, geometrical or optical isomers cannot be assessed and such answers will not gain credit.
- Curly arrows in reaction mechanisms must always begin and end in the right places. They must be clearly full-headed or half-headed, as appropriate.
- Numerical answers should generally be given to two or three significant figures, but candidates should abide by instructions on the number of significant figures required in their answer.

General comments

Candidates found much of the paper was straightforward. **Question 6** enabled better performing candidates to demonstrate their abilities.

There was little evidence of candidates running out of time. There were very few blank answer spaces.

Comments on specific questions

Question 1

(a) (i) This recall question was generally well answered and almost all candidates could correctly state the trend. Most could relate it correctly to the ionic radius increasing and the effect on the carbonate ion. The most common omissions were not indicating the ion when referencing the radius or size and not indicating that it was the anion being polarised. A few candidates incorrectly referred to the ionic bond.

(ii) This was generally well answered, with only a few candidates adding oxygen or, having an incorrect formula for the carbonate, generating oxygen. These candidates possibly confused the carbonate decomposition with that of a nitrate. Some candidates incorrectly gave answers for cobalt or calcium carbonate.

(b) (i) This was challenging for many candidates. Common errors included, either not counting electrons correctly, confusing the ion with the atom or losing 3d electrons rather than 4s. Almost all candidates paired electrons correctly with opposite spin.

(ii) Many good answers were seen and candidates were able to recall the $3d_{z^2}$ orbital correctly. The most common incorrect answers were either a p_z or a different 3d orbital.

(iii) Most candidates gained credit for this question. The most common incorrect answer was stating that the d-subshell was energetically accessible.

(c) (i) Most candidates gave a good explanation. Common errors were seen, such as not stating metal atom/ion as the recipient of the coordinate bonds. The standard of English is important here as 'donates two lone pair electrons' suggests two electrons are donated from one lone pair and thus is incorrect. However, the more common 'has two pairs of lone pairs' was given credit.

(ii) This was very well done by almost all candidates. Excellent renditions of three-dimensional octahedral structures were seen and the isomers were mostly correct. Candidates commonly drew the two optical isomers as mirror images, which is good practice and is to be encouraged. Of those who did not, several inadvertently drew identical cis isomers. Candidates were keen to show the waters being attached through the oxygen atoms, but should guard against writing 'O_2H', which is incorrect. Where the three-dimensional bonds were incorrect, no credit was given as the isomers could not be correctly represented.

(iii) Most candidates correctly identified both types of isomerism.

(iv) This was found to be difficult. As well as identifying the correct isomer, candidates had to explain why it was polar. 'Dipoles do not cancel' was the most common correct answer, but 'dipole moments do not cancel' was also accepted even though the term 'dipole moment' normally refers to the overall dipole. A significant proportion of candidates chose the trans isomer and explained why it was not polar and so did not receive credit. Candidates should be aware that simply stating 'it is not symmetrical' without reference to polar bonds or dipoles in the molecule is not enough to explain an overall dipole moment.

(d)(i) Candidates found this difficult and most did not realise that, of the two metals, aluminium is far more likely to be able to form complexes.

(ii) Almost all candidates found this calculation straightforward. A very common mistake was using three significant figures rather than the requested two. Other mistakes seen were the division by three for the stoichiometry of the half-equation given or using the M_r of aluminium oxide rather than aluminium metal.

Question 2

(a)(i) Candidates were expected to know that the reaction is conducted under anhydrous conditions and so hydrogen chloride gas is produced which reacts with moisture in the air to produce white/steamy fumes. As one reactant is liquid, 'bubbles' was given credit, but formation of a white precipitate would not be seen.

(ii) The correct form of words was required as this was definition. A good proportion of candidates could recall this. The most common omission was the word 'number'. Candidates should be made aware that the older 'measure of disorder in a system' will not be accepted in future series.

(iii) Some good answers were seen, however, this question was not clearly understood by many candidates who wrote why $\Delta S^\ominus$ was positive, rather than why it had a large positive value. The answer had to emphasise that lots of gas was produced or state the number of moles of gas produced.

(iv) This calculation involved a determination of ΔH followed by use of $\Delta G = \Delta H - T\Delta S$. Most candidates could correctly calculate ΔH given the ΔH_f data. Almost all could recall the equation for ΔG and most were able to produce a correct final answer. The most common errors were an incorrect sign on ΔH, using 25 °C rather than 298K and not dividing the ΔS value by 1000.

(b)(i) Most candidates found this difficult and did not gain credit. Candidates were expected to form H^+, as an acidic solution remains, and write an ionic equation. Of those who attempted the question, the most common errors were either to include chlorine or produce oxygen.

(ii) Most candidates gained some, if not all, credit. Common errors were not identifying the split orbitals as d-orbitals, stating that they were in Ba and not mentioning the electron when talking about promotion or excitation. It was clear that many candidates prepared using a past paper with a question about complexes of different colours and statements such as 'ΔE is different' and 'different wavelengths absorbed' were commonly seen.

(c) This was generally well answered. Almost all candidates knew that both the ΔH_{latt} and ΔH_{hyd} became more endothermic and that ΔH_{sol} became more endothermic. ΔH_{hyd} being the more significant change was less well known.

Question 3

(a) (i) This was generally well answered with most candidates stating the expression clearly and able to deduce the units. A significant minority put an equilibrium expression involving ($Ni(IO_3)_2$) and the other common error was to omit charges on the ions.

(ii) Almost all candidates with the correct expression in **(i)** were able to calculate the value in **(ii)**, with only a few forgetting to double the iodate concentration.

(b)(i) Almost all candidates could calculate E_{cell} and indicate the positive electrode correctly.

(ii) Few candidates gave their answer in terms of E_{cell} becoming more positive or negative. Candidates should understand that where a value could be positive or negative, their answer must be given in terms of more positive or more negative, rather than just 'lower' or 'smaller', which are ambiguous terms and could refer to the magnitude of the value. It was clear that some candidates knew the answer but used ambiguous language or referred only to E rather than E_{cell}.

(iii) Most candidates saw that addition of a soluble nickel salt would cause the common ion effect, but fewer also stated that this reduced the iodate concentration.

(c) (i) Almost all candidates were able to calculate [H^+] correctly.

(ii) Fewer could then deduce the equilibrium concentrations of the acid and conjugate base, with the most common errors either having the acid concentration as '1' or equal to the iodate concentration.

(iii) Most candidates could take their values and correctly calculate K_a.

(d)(i) The definition of a buffer solution was well known by most candidates. Grammatical errors made a difference as adding a small amount of the buffer solution to an acid or base was incorrect, as was adding moderate amounts of acid or base to a buffer. Candidates were aware that the pH is not constant when a buffer is used.

(ii) Calculation of the rate constant and its units were well done.

(iii) Most candidates chose to calculate the rate using their rate constant calculated in **(ii)**, without seeing that tripling a squared concentration in the rate equation just meant the original rate could be multiplied by 9 to obtain the answer.

Question 4

(a) Although many candidates knew the types of polymerisation, a large proportion misread the question and attempted structures of intermediates rather than monomers. Candidates should be encouraged to read the questions carefully to establish what is being asked before setting out their answers. The attachment to the ester group for the addition polymer is important and incorrect attachments (for example, to an oxygen in $COOCH_3$) were seen.

(b) Most candidates knew that an isoelectric point is a pH where the amino acid is a zwitterion. A few neglected to state it is a pH value or talked about a neutral solution rather than a neutral (overall) ion.

(c)(i) Most candidates knew that glycine, being at its isoelectric point, did not move from the cross. Fewer managed to get glutamic acid and lysine on the correct, opposite sides. A small number of candidates did not label their diagram.

(ii) A reasonable proportion of candidates could see that, on the increase in pH, glycine would be negatively charged and so move towards the positive electrode.

Question 5

(a)(i) Most candidates could see which bond was hydrolysed in atorvastatin. Incorrect answers mostly involved either the C=C bonds in the ring or the carboxylic acid group.

(ii) Many candidates focused on atorvastatin's ability to form hydrogen bonds, but far fewer could see that the forming of hydrogen bonds with the solvent, water, led to the molecule's solubility.

(iii) Most candidates could deduce the formula, with a mixture of errors from those who could not.

(iv) Most candidates managed to identify correctly the two chiral carbons in the structure. Incorrect answers generally included the carbons in the heterocyclic ring or the central carbon in the isopropyl group.

(v) Many good answers were seen. The reasons to produce only one optical isomer are all based on the specification answer, which is that the enantiomers have different biological activity. Less specific answers, such as 'reduce side effects' or 'lower dose' were not given credit.

(b) (i) Few candidates were able to use the structure given and the table of data to deduce how many peaks would appear in the given range.

(ii) Almost all candidates knew this involved NH and OH peaks. Fewer gave the correct number of missing peaks and fewer still could describe proton exchange correctly.

(c) This question proved a challenge for most candidates. They could see that the carboxylic acid would be reduced to an alcohol, but fewer could see that the amide would reduce to an amine. Many incorrect answers were seen, including reductions of phenol, aldehydes and ketones.

Question 6

(a) Many good answers were seen and most candidates gained some credit. Candidates who performed less well did not understand the question and gave observations for the tests rather than the functional groups involved. A number of candidates did not spot that the tests were for groups in aliphatic compounds and put phenol as an answer.

(b)(i) Most candidates could see that an alcohol group was present in **A** and the best responses classified it as primary.

(ii) Fewer candidates gained full credit in **(ii)**, with the most common error in the **E**→**F** reaction, where many classified it as condensation. Candidates should be aware that condensation reactions involve the coming together of two molecules and, on their joining, a small molecule is lost, which is distinct from the elimination reaction here.

(iii) Candidates had to use the formula given and the test results to deduce the structures of two molecules. The majority managed **H**, but far fewer could elucidate **G**. Candidates should be aware that a reaction with hot concentrated acidified $KMnO_4$ will not yield an alcohol.

(iv) Where the structures of **G** and **H** were correct, most candidates could go on to gain some credit in **(iv)**, although fewer could take the synthetic route all the way back to a correct structure for **A**. Many candidates gave the correct structure for **D** and made creditable attempts at the rest.

On questions such as these, candidates should be made aware that when a formula is given, their structure must match this or no credit can be given.

Question 7

(a) Most candidates performed well here. Occasionally, it was unclear in the text which compound they were addressing (it was assumed that the statements were in the same order as the relative acidities stated above), but otherwise the explanations were clear. Candidates were able to explain acidic strength both in terms of the ease of loss of H^+ and the stability of the conjugate base. General statements such as 'acidity refers to the ability to lose H^+' were not given credit.

(b) This was generally well answered. Candidates who performed less well struggled to see that the nitration of a benzene ring simply replaced a hydrogen with a nitro group on the ring.

(c)(i) Many candidates were able to name the ester correctly and spell the name correctly. Weaker responses attempted only to name the functional group.

(ii) Many candidates struggled with the mechanism, although some excellent answers were seen. Most could add a lone pair to the oxygen of ROH and draw a curly arrow to attack the carbonyl carbon. Fewer polarised the C=O bond correctly. The intermediate proved a challenge and many put a $–O^+H_2$ group rather than $–O^+RH$, perhaps recalling hydrolysis of an acyl chloride. Many candidates did not take enough care over mechanistic diagrams; curly arrows should always originate from a lone pair, a bond or a negative charge. Some candidates broke the O–H bond with the electrons going towards the H, which would result in a hydride ion.

(iii) A number of candidates gave the correct name for the mechanism. 'Nucleophilic' or 'electrophilic' substitution were the most common incorrect answers.

Question 8

(a)(i) Most candidates could recall the definition. Candidates should be aware that, as lattice energy is defined as the energy released on forming the lattice, stating 'energy required' is not correct. Candidates should also be aware that you cannot form one mole of lattice from one mole of ions.

(ii) Most candidates gave a correct definition, but several did not name the solvent.

(b) This was generally very well done and candidates could write the expression for ΔH_{sol} correctly using the terms provided. The most common error was reversing the expression to give $–\Delta H_{sol}$.

(c) Most candidates attempted the question and many gained full marks. Several omitted the electron on the highest energy level, but it was clear that candidates had good knowledge of the Born-Haber cycle and could apply it. Some candidates struggled with elemental C*l* being diatomic.

(d) Candidates had to apply their knowledge to a novel context and better performing candidates tended to give good answers. Data was not given so candidates were required to determine which had the smaller ionic radius and then use their guess to explain which had the more exothermic ΔH_{hyd}. No credit was available for the choice of ion, as the ionic radii are similar, but the linking of the stronger ion-dipole forces with water and the more exothermic ΔH_{hyd} were credited. Some candidates went down the alternative route and talked of number of lone pairs on oxygen and hydrogen bonding with water and gained equal credit.

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Key messages

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- Candidates should read the information provided in the questions carefully and use it to help them answer the questions. (For example, **Question 1(a)** and **Question 2(b)**.)

General comments

Most candidates attempted all questions, and a range of marks was seen. The paper was challenging in places, and some candidates may not have appreciated the level of the answers required.

Overall, **Question 2** was answered better than **Question 1**. **Question 2** included more of the data handling and graph questions which are generally answered better than questions on practical methods and techniques.

Comments on specific questions

Question 1

(a) Table 1.1 provided detailed information about hazards and candidates were required to use this. Most knew that gloves were to protect from a skin irritant, but some did not name bromobenzene. Candidates were expected to realise that a fume hood was for toxic gases. Common mistakes were not appreciating that a fume hood is used to remove gases, for suggesting everything gave off a toxic gas and for suggesting that a fume hood is for flammable substances.

(b) (i) Candidates were not familiar with the idea of drying glassware before an experiment and an answer saying how to heat the glassware was expected, not just that it should be heated. Answers which might leave traces in the glassware, such as drying with a towel or using a chemical were rejected.

(ii) Many candidates gave the correct answer of distillation, noting the boiling points provided in the table. A common wrong answer was to ignore the boiling point data provided and say the water would evaporate.

(c) (i) This question was answered well but could be answered even better. Some candidates are still opting for water in at the top of the condenser and a minority had water entering in other places.

(ii) Very few candidates came up with the correct suggestion that solid **Z** was used to prevent water from entering. Candidates were not expected to be familiar with the concept of air/gases entering the apparatus, but it was assumed they could make sensible suggestions from their practical experience. Most answers were about air/gases leaving.

(iii) The question was answered correctly by about half the candidates who recognised that if the bung were present there could be a build-up of pressure in the apparatus. Quite a few appreciated that gas needed to escape but did not take their answer any further and so did not gain credit. Some candidates linked this to their answer for **(c)(ii)** which did not help them.

(d) This question was one of the better answered questions overall. Many candidates had an understanding of weighing by difference, but some gave the incorrect answer ‘weigh empty boat, then boat and Mg and find difference’. Very good presentation of the table was seen with clear headings and units for all measurements. Some candidates did not know what a weighing boat was and a few incorrectly weighed by difference using the flask or some other vessel.

(e) This question was answered well. The most common method was to use the given M_r and multiply by the number of moles used (0.05) to obtain the mass used, then find the volume by dividing by the density given. The most common error was to calc M_r/density = 104.6 but there were other errors including truncating the answer to the first step so that there was a rounding error.

(f) There were many different answers here. Few candidates realised the dropwise action of adding bromobenzene was to reduce the rate of reaction and of those who did, some did not suggest a reason why the reaction needed to be controlled. Incorrect answers included writing about other steps in the procedure such as being able to see the end-point of the titration better.

(g) In general, this question was well-answered but weaker responses did not pick up on the idea that HCl was in excess. Stating that the measuring cylinder was accurate enough or easy to use was not worth credit. Some also said why a pipette was not suitable, which did not answer the question.

(h) This question was one of the more challenging one-mark questions on the paper. The candidates had to correctly identify beaker **B** and explain that ethoxyethane has a lower density than water and hence show a detailed understanding of the use of a separating funnel and that the layers would be an ethoxyethane (organic) layer and a water (aqueous) layer. Many incorrectly chose beaker **A**, basing their argument on the density of the product rather than using the information given in the question that the product was in the ethoxyethane layer. Of those who stated beaker **B**, few continued to give the comparison between ethoxyethane and water, some saying ethoxyethane had the lowest density and others concentrating on the density of the product or reactants rather than the solvents.

(i) (i) Very few entirely correct answers were seen and some candidates did not attempt this question. More than half calculated the correct percentage yield, based on bromoethane being the limiting reagent, even when they did not show that bromobenzene was the limiting reagent correctly or even attempt to. A common mistaken approach was to calculate the number of moles of 1-phenylethanol formed without considering which reactant was in excess. If the value of moles for 1-phenylethanol was calculated first, it was often mistakenly used as the number of moles of ethanal instead of using the density data and volume data ($3\,cm^3$) provided to calculate the number of moles of ethanal.

(ii) Ethanal being the cause of the C=O peak was suggested by most. A few gave the other acceptable answers of product oxidation or a by-product with C=O present. Incorrect answers included that ethoxyethane contained a C=O or the product would still give a peak at the C=O frequency due to its structure despite not containing a C=O.

Question 2

(a) The expected answers are about the direct consequences of adding the reaction mixture to iced water, namely, lowering the temperature and diluting the reactants. More candidates included lowering the temperature than dilution. Other candidates chose to answer using particle theory and gained a maximum of one mark for correctly discussing either the energy of the particles or the frequency of collisions of the particles.

(b) The colours of the phenolphthalein in acidic and alkaline conditions were given in the question and candidates were expected to use this information rather than just answering ‘the colour changes’. Most candidates who described the colour change had the correct answer of change to pink although some got the colour change back to front.

(c) (i) This was well done by many of the candidates who read the instructions and gave the correct number of decimal places and significant figures for the calculation. A few errors in rounding or calculations resulted in more errors in column 4 than column 3. A few candidates used the time value of 180 minutes instead of the titre value at 180 minutes to calculate their log value which made the subsequent answers incorrect. Some gave column 4 to four decimal places instead of four significant figures.

(ii) In general, the candidates were very good at plotting the graph and drawing a line of best fit. Common errors included misplotting the first point at time = 0 minutes, presumably before working out the scale was one small square to 0.005 on the *y*-axis. Candidates should be encouraged to check back at the end. The other mistake was to round the correct log data in the table to the nearest three significant figures and so plotting the points on the horizontal lines rather than mostly between them. For example, 1.528 became 1.53.

The line of best fit was normally correct. The points plotted correctly were approximately on the line of best fit with a clear anomalous point. The point chosen as anomalous should not be considered when drawing the line of best fit. Candidates are advised to follow the given instructions to plot the points as neat crosses and not dots, so the plotted points can be clearly seen and to aid drawing the line of best fit.

(iii) Practically all candidates identified a correct anomalous point, but few were able to explain it. The most common errors were to discuss the titre, the timing of the titration or referring to stopping or starting a stop-clock rather than discussing the sample. The titration will always be done after the sample has been removed and quenched so it is the timing of the sample removal (and quenching) which is important and not the timing of the titration.

(iv) The candidates were generally very good at the gradient calculation. A number of candidates did not pick two points from their line of best fit that were far enough apart; the points are expected to cover at least half the range of the line of best fit. Also, points must be on the line of best fit so if chosen from the table they must be exactly on the line of best fit. The most common mistake was to give the answer to the wrong number of significant figures. Unfortunately, a number of candidates who calculated a gradient value of –0.0120 then wrote down their calculator reading of –0.012.

(d) Some candidates struggled to see that the gradient was equal to $-k \div 2.303$, so they tried to use the full equation, but instead of using the intercept at zero (about 1.53) as the constant they used the gradient value. Those that did get as far are working out *k* from the gradient (or the full equation) often did not convert the answer from min^{-1} to s^{-1}. If a conversion was attempted multiplying by 60 instead of dividing by 60 was a common mistake. Candidates are recommended to write their method clearly step by step.

(e) Some candidates gave the accepted answer of 'No, because there was an anomalous point'.

(f) About half of the candidates answered this correctly, although some did not attempt an answer. Common errors were to draw a line from the same starting point but of a lower gradient and drawing a line of higher gradient from a different starting point.

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Key messages

- Candidates should read through the details of an experiment before attempting to answer sub-questions based upon the experiment.

- It was apparent that many candidates did not fully understand the experiment in **Question 1** as answers to **1(c)** and **1(f)** suggested these candidates did not appreciate that no reaction occurred and answers to **1(g)(v)** suggested many assumed the stop-watch was stopped and restarted during the experiment.

- If one answer is required, candidates should refrain from giving two (or more) answers in case their second answer is incorrect. This was often evident in **Question 1(e)** where the answer given was ‘burette (correct) or measuring cylinder (incorrect)’.

- Data points on graphs should be plotted correctly using a sharp pencil; sometimes points were feint and difficult to see, as in **Question 1(g)(ii)**.

General comments

Nearly all candidates completed the examination and there were very few omitted questions.

When not specifically asked for, the number of significant figures and/or decimal points used was a problem for some candidates. Usually, most numerical answers, if not indicated otherwise, should be to three significant figures. At A Level, an answer to a calculation given to one significant figure will generally be insufficient.

Candidates should ensure their calculators are set to allow for the correct order of mathematical operations (commonly known as ‘BODMAS’).

Comments on specific questions

Question 1

(a) (i) Most candidates were able to do this relatively straightforward calculation.

(ii) Many candidates were able to describe the process to make a standard solution. Candidates who used a series of numbered steps as required by the question tended to perform better than those who did not.

Common omissions and errors were:
- Not stating that distilled water is used in all steps.
- Not stating the solid is **dissolved** in distilled water in step 1. ‘Add distilled water’ alone is insufficient.
- The use of pipettes or burettes to transfer the solution into a volumetric flask in step 2. The use of both these pieces of apparatus would result in some solution being discarded in the pre-rinsing stage.
- Not using the correct sized volumetric flask in step 2 (500 cm^3). 250 cm^3 was frequently used.
- Using the instruction ‘stir the (contents of the) volumetric flask’ in step 3 instead of ‘invert the stoppered flask’.

Candidates who performed less well assumed they were preparing the standard solution from aqueous ethanedioic acid.

(b) Most candidates gave the phrase used in the syllabus i.e. 'chemically resistant gloves' but many only stated 'gloves', which was insufficient as not all gloves offer the required degree of protection.

(c) Many candidates did not appreciate what activated carbon is, despite the very first line of the question telling them exactly what it does. Only a small number of candidates provided the correct answer about removing water/moisture from the surface of the activated carbon.

Common errors included:
- 'to activate the carbon'
- 'to increase the rate of reaction'.

(d) The majority of candidates correctly calculated this volume. Candidates should check their answer makes sense. Some answers exceeded 100 cm^3, which was more than the target volume.

(e) The expected answer, 'burette' was given by most candidates. '50 cm^3 volumetric pipette' was also accepted. 'Pipette' alone was considered too vague.

(f) The concept that shaking the flask prior to removal of the sample ensured the sample was representative and had the same constituency as the mixture remaining in the flask and vice versa, thus not affecting the change of rate of adsorption in the flask, was not appreciated by many candidates.

Incorrect answers focused on reaction rate or completion of reaction or rate of carbon dissolving.

(g) (i) The mass readings for non-adsorbed $(COOH)_2$ were to two decimal places, as was the mass of adsorbed $(COOH)_2$ given in row 1. This should have provided candidates with the knowledge all mass readings in the third column should be to two decimal places. Frequently, this was not done.

Some candidates incorrectly produced values in the third column which gave plots outside the grid in Fig. 1.1 in **1(g)(ii)**. These candidates should have realised that an error had been made and should have rechecked their answers to **1(g)(i)**.

(ii) Most candidates answered this correctly, but some encountered difficulties drawing smooth curved lines of best fit with some evidence of drawing lines from plot to plot seen.

Common errors were:
- not plotting the point at (0,0)
- starting the line of best fit from the second point.

(iii) Most candidates knew that time was the independent variable.

(iv) Most candidates could suggest a variable that needed to be controlled, 'temperature (of the reaction mixture)' being the most common correct answer.

Candidates who did not gain credit almost always gave a control variable that was already fixed in the experimental procedure – e.g. mass of activated carbon or volume of solution sampled.

(v) Nearly all candidates correctly identified the anomalous point and many went on to state that the sample had been withdrawn before the recorded time in the table (30 minutes). The most common error was to suggest that the stop-watch was started or stopped too early or too late. This could not be correct as it was a continuous experiment, all results would have been affected by such an error.

(h) (i) Many candidates answered this correctly. A few incorrectly used points from Table 1.2 when they did not know whether or not they were on the line of best fit; most were not. Others chose to take readings too close to each other; a separation of 5 units on the *x*-axis was the minimum accepted. The calculation and units were very well answered, with the latter being expected in the form $g\,mg^{-1}$, rather than g / mg.

(ii) Many candidates chose the straightforward way to answer this by taking the inverse of the answer to **1(h)(i)**. Other candidates chose to use $y = mx + c$, using values from Table 1.2, but these points were not on the line of best fit.

(i) Although the majority of the candidates answered this correctly, it was apparent that many struggled to choose a simple method to determine that the difference between the data book value and the experimental value was too far apart to be accounted for by the 6.5% quoted for experimental error.

A significant number of candidates managed to do a valid calculation but then chose the wrong explanation to support their calculation.

The most common error was to base the calculation on 6.5% of the data book value rather than the experimental value.

Question 2

(a) Most candidates completed Table 2.1 correctly. The most common error was the omission of the second decimal place, a zero, for the mass of butane burned.

(b) Most candidates correctly applied the relationship $q = mc\Delta T$ given in the question.

(c) Many candidates knew how to complete this calculation but ignored the instruction to give their answer to three significant figures or missed out the negative sign in their final answer. Enthalpies of combustion must be exothermic.

(d) Many candidates correctly suggested the water in the can should be stirred.

(e) Many candidates showed their working for this calculation and correctly appreciated that the error in the reading (half of the $5\,\text{cm}^3$ graduation) does not need doubling as using a measuring cylinder only needs one reading. Many candidates chose to determine the error as a percentage of the volume of the apparatus ($500\,\text{cm}^3$) instead of the volume measured ($320\,\text{cm}^3$).

(f) The accepted correct answers of either using a lid or using insulation were frequently seen. A significant number of candidates opted for inappropriate material for insulation, such as polystyrene, which would ignite when heated by an open flame.

(g) (i) The majority of candidates knew that a smaller value for temperature change and/or mass of butane combusted would lead to a greater percentage error, thus reducing the accuracy.

(ii) The simple idea that less heat loss and/or less evaporation of water as a result of less heating would improve the accuracy of the experiment was appreciated by relatively few candidates. Many weaker responses suggested that a smaller value for temperature change and/or mass of butane combusted would occur without realising this would reduce accuracy.

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(iii) The question was answered correctly by about half the candidates who recognised that if the bung were present there could be a build-up of pressure in the apparatus. Quite a few appreciated that gas needed to escape but did not take their answer any further and so did not gain credit. Some candidates linked this to their answer for **(c)(ii)** which did not help them.

(d) This question was one of the better answered questions overall. Many candidates had an understanding of weighing by difference, but some gave the incorrect answer ‘weigh empty boat, then boat and Mg and find difference’. Very good presentation of the table was seen with clear headings and units for all measurements. Some candidates did not know what a weighing boat was and a few incorrectly weighed by difference using the flask or some other vessel.

(e) This question was answered well. The most common method was to use the given M_r and multiply by the number of moles used (0.05) to obtain the mass used, then find the volume by dividing by the density given. The most common error was to calc M_r/density = 104.6 but there were other errors including truncating the answer to the first step so that there was a rounding error.

(f) There were many different answers here. Few candidates realised the dropwise action of adding bromobenzene was to reduce the rate of reaction and of those who did, some did not suggest a reason why the reaction needed to be controlled. Incorrect answers included writing about other steps in the procedure such as being able to see the end-point of the titration better.

(g) In general, this question was well-answered but weaker responses did not pick up on the idea that HCl was in excess. Stating that the measuring cylinder was accurate enough or easy to use was not worth credit. Some also said why a pipette was not suitable, which did not answer the question.

(h) This question was one of the more challenging one-mark questions on the paper. The candidates had to correctly identify beaker **B** and explain that ethoxyethane has a lower density than water and hence show a detailed understanding of the use of a separating funnel and that the layers would be an ethoxyethane (organic) layer and a water (aqueous) layer. Many incorrectly chose beaker **A**, basing their argument on the density of the product rather than using the information given in the question that the product was in the ethoxyethane layer. Of those who stated beaker **B**, few continued to give the comparison between ethoxyethane and water, some saying ethoxyethane had the lowest density and others concentrating on the density of the product or reactants rather than the solvents.

(i) (i) Very few entirely correct answers were seen and some candidates did not attempt this question. More than half calculated the correct percentage yield, based on bromoethane being the limiting reagent, even when they did not show that bromobenzene was the limiting reagent correctly or even attempt to. A common mistaken approach was to calculate the number of moles of 1-phenylethanol formed without considering which reactant was in excess. If the value of moles for 1-phenylethanol was calculated first, it was often mistakenly used as the number of moles of ethanal instead of using the density data and volume data (3 cm^3) provided to calculate the number of moles of ethanal.

(ii) Ethanal being the cause of the C=O peak was suggested by most. A few gave the other acceptable answers of product oxidation or a by-product with C=O present. Incorrect answers included that ethoxyethane contained a C=O or the product would still give a peak at the C=O frequency due to its structure despite not containing a C=O.

Question 2

(a) The expected answers are about the direct consequences of adding the reaction mixture to iced water, namely, lowering the temperature and diluting the reactants. More candidates included lowering the temperature than dilution. Other candidates chose to answer using particle theory and gained a maximum of one mark for correctly discussing either the energy of the particles or the frequency of collisions of the particles.

(b) The colours of the phenolphthalein in acidic and alkaline conditions were given in the question and candidates were expected to use this information rather than just answering ‘the colour changes’. Most candidates who described the colour change had the correct answer of change to pink although some got the colour change back to front.

(c) (i) This was well done by many of the candidates who read the instructions and gave the correct number of decimal places and significant figures for the calculation. A few errors in rounding or calculations resulted in more errors in column 4 than column 3. A few candidates used the time value of 180 minutes instead of the titre value at 180 minutes to calculate their log value which made the subsequent answers incorrect. Some gave column 4 to four decimal places instead of four significant figures.

(ii) In general, the candidates were very good at plotting the graph and drawing a line of best fit. Common errors included misplotting the first point at time = 0 minutes, presumably before working out the scale was one small square to 0.005 on the *y*-axis. Candidates should be encouraged to check back at the end. The other mistake was to round the correct log data in the table to the nearest three significant figures and so plotting the points on the horizontal lines rather than mostly between them. For example, 1.528 became 1.53.

The line of best fit was normally correct. The points plotted correctly were approximately on the line of best fit with a clear anomalous point. The point chosen as anomalous should not be considered when drawing the line of best fit. Candidates are advised to follow the given instructions to plot the points as neat crosses and not dots, so the plotted points can be clearly seen and to aid drawing the line of best fit.

(iii) Practically all candidates identified a correct anomalous point, but few were able to explain it. The most common errors were to discuss the titre, the timing of the titration or referring to stopping or starting a stop-clock rather than discussing the sample. The titration will always be done after the sample has been removed and quenched so it is the timing of the sample removal (and quenching) which is important and not the timing of the titration.

(iv) The candidates were generally very good at the gradient calculation. A number of candidates did not pick two points from their line of best fit that were far enough apart; the points are expected to cover at least half the range of the line of best fit. Also, points must be on the line of best fit so if chosen from the table they must be exactly on the line of best fit. The most common mistake was to give the answer to the wrong number of significant figures. Unfortunately, a number of candidates who calculated a gradient value of –0.0120 then wrote down their calculator reading of –0.012.

(d) Some candidates struggled to see that the gradient was equal to $-k \div 2.303$, so they tried to use the full equation, but instead of using the intercept at zero (about 1.53) as the constant they used the gradient value. Those that did get as far are working out *k* from the gradient (or the full equation) often did not convert the answer from min^{-1} to s^{-1}. If a conversion was attempted multiplying by 60 instead of dividing by 60 was a common mistake. Candidates are recommended to write their method clearly step by step.

(e) Some candidates gave the accepted answer of ‘No, because there was an anomalous point’.

(f) About half of the candidates answered this correctly, although some did not attempt an answer. Common errors were to draw a line from the same starting point but of a lower gradient and drawing a line of higher gradient from a different starting point.

CHEMISTRY

Paper 9701/54
Planning, Analysis and Evaluation

Key messages

- Most candidates could perform calculations correctly and read data accurately but should take care to use significant figures correctly and avoid premature rounding.
- There were common misunderstandings about the purpose of important experimental steps. Firsthand experience of practical work and analysis of experiment design are highly recommended when preparing for this paper.
- While graph work and analysis of data was generally well done, fewer candidates were able to suggest plausible explanations for the anomalous reading. This is another skill that can be practised and enhanced as part of hands-on practical investigations.

General comments

In general, the candidates answered well, reflecting the quality of their preparation by centres. There were few very low marks, and the paper proved to be accessible to most candidates. There were very few no response questions and all but a few candidates produced completely legible responses.

Comments on specific questions

Question 1

(a) (i) Nearly all candidates were able to read the density of water at 23.0 °C from the graph (Fig. 1.1) correctly.

(ii) Most candidates were able to complete this calculation correctly. It is worth noting that there is no justification for rounding before the final answer in a two-step calculation.

(b) (i) This was the first of three question parts assessing the candidate's understanding of the experimental method conducted by the student. The candidate had to explain that the flask containing vaporised **Y** was kept in boiling water for 3 minutes in step 5, to ensure that the vapour reached the temperature of the boiling water bath (100 °C). Some candidates misunderstood the procedure and incorrectly suggested that some **Y** still needed to be evaporated, or a chemical reaction was taking place, neither of which gained credit.

(ii) Although more candidates gained credit for this part than for **(b)(i)**, many responses revealed a lack of understanding of the purpose behind the various steps of the method. The key point here is that the calculation of M_r is based on the mass of the vapour occupying the flask – the mass of the liquid is not required to complete the calculation.

(iii) Fewer than half of the candidates were able to correctly identify the appropriate safety precaution to take in this context, namely the use of a fume hood when managing hazardous gases.

Candidates should be familiar with the safety measures required for specific types of hazard:

- A face mask is appropriate for protection against hazardous particulates.
- Avoidance of naked flames is essential when handling flammable substances.
- Chemically resistant gloves should be worn when dealing with irritant materials.

(c) (i) This question was not well answered.

To answer correctly, candidates needed to apply the principle that the uncertainty in a single mass measurement is estimated as half the smallest scale division. In this case, the balance displayed mass to three decimal places, so the uncertainty in each measurement is ±0.0005 g.

As the mass of the solid sample is determined by the difference between two balance readings (the mass recorded in the table and zero), the absolute uncertainty in the calculated mass is the sum of the uncertainties from each reading: (±0.0005 g) × 2 = ±0.001 g.

The inclusion of clear working showing that the candidate had used these steps was essential.

Common answers which were not creditworthy included:

$\frac{0.001 \times 100}{31.123} = 0.00321\%$ or $\frac{0.0005 \times 100}{31.123} = 0.00161\%$ or $\frac{2 \times 0.001 \times 100}{31.123} = 0.00643\%$

(ii) This two-step calculation was generally well answered. Candidates should be advised to avoid premature rounding in multi-step calculations and to retain full calculator values throughout the calculation, only rounding the final answer in line with the precision of the data provided.

(iii) Almost all candidates completed this calculation correctly.

(d) If the actual temperature of the vapour was lower than 100 °C, the mass of vapour remaining in the conical flask would be greater than it would have been at the higher temperature. This means that the calculation of M_r using this mass would produce a value for the M_r greater than the true value.

(e) The majority of candidates correctly recognised that a water bath can only reach 100 °C. They understood that this is insufficient to vaporise methylbenzene, which has a boiling point of 111 °C. As a result, methylbenzene would not fully vaporise under these conditions, making this method unsuitable for determining its M_r .

Question 2

(a) Most candidates were able to calculate the mass of $Cu(NO_3)_2{\bullet}3H_2O(s)$ needed to produce the required volume of 1.00 mol dm^{-3} $Cu(NO_3)_2(aq)$. Most candidates gave their answer to 4 or, less frequently, 3 significant figures, both of which gained credit. Only a few gave the answer to 2 significant figures. Incorrect rounding was rare. Some candidates used 64 for the A_r of Cu, instead of 63.5 given in the Periodic Table printed in the paper. Where data is needed to perform a calculation candidates should use the values given in the paper.

(b) The preparation of a standard solution is a routine laboratory procedure and the majority of candidates demonstrated familiarity with the steps involved using careful attention to detail and correct terminology.

The question stem provided a clear starting point: a small beaker containing the calculated mass of $Cu(NO_3)_2{\bullet}3H_2O(s)$ from **(a)**. From this, candidates were expected to outline the standard method for preparing a solution of accurately known concentration using this hydrated salt.

A few common errors/omissions were:

- Some candidates incorrectly suggested heating the $Cu(NO_3)_2•3H_2O(s)$ to remove the water of crystallisation before dissolving it. This is not appropriate when preparing a solution of known concentration using the hydrated salt.
- Several responses referred incorrectly to the solid being dissolved as $Cu(NO_3)_2$ rather than the correct hydrated form, $Cu(NO_3)_2\ 3H_2O$.
- A few candidates misunderstood the purpose of inverting the volumetric flask after filling to the mark, stating it was to dissolve any remaining solid. In fact, inversion is done to ensure the resulting solution is homogeneous. All the solid should be fully dissolved before transferring the solution to the flask and topping up.
- Some responses incorrectly described using a beaker, measuring cylinder, or conical flask to make up the final solution, rather than a volumetric flask.

(c) Simply identifying that **A** acts as a salt bridge was sufficient to gain credit. However, more complete answers explained the function of the salt bridge — namely, that it allows the transfer of ions between the two half-cells to maintain electrical neutrality.

Responses that incorrectly stated that electrons transfer across the salt bridge were not credited. This reflects a common misconception and candidates should be reminded that electron flow occurs through the external circuit, not the salt bridge.

(d) Calculating the correct values for the table of results was completed accurately by nearly all candidates.

(e) Recognition of the independent variable as the concentration of $\mathbf{M}^{n+}$ was achieved by nearly all candidates. No credit was given for identifying log [$\mathbf{M}^{n+}$] as the independent variable, as this is a derived value used for graphing or analysis, not the variable that was directly manipulated in the experiment.

(f) (i) Most candidates plotted data points on the grid with appropriate accuracy and drew a suitable line of best fit. In this question, the line of best fit should be a straight line that passed very close to all but the anomalous point.

(ii) Nearly all candidates were able to correctly identify the anomalous point on the graph. However, a much smaller proportion were able to offer a valid explanation for the cause of the anomaly.

In this case, the anomalous result at a concentration of $5.00 \times 10^{-4}\,mol\,dm^{-3}$ could be attributed to the actual concentration of the solution being lower than that stated in the table. This would lead to a deviation from the expected linear trend when the data is plotted, as the electrode potential would correspond to a lower ion concentration than assumed. Candidates should be encouraged not only to recognise anomalies but also to consider experimental errors or procedural issues that could account for such deviations.

(iii) Simply 'taking more readings' or 'repeating the experiment' does not improve reliability. These extra experimental measurements had to be used to eliminate anomalies.

(g) (i) Most candidates correctly identified suitable coordinate pairs (x, y) from the line of best fit, ensuring they were in the correct format and selected across a sufficiently large range — typically covering at least half the span of the data. The majority of candidates also calculated the gradient accurately and expressed their final answer to three significant figures, as required.

(ii) Most candidates demonstrated a sound understanding of how the Nernst equation can be interpreted in the form of a linear equation, $y = mx + c$. They were generally able to correctly identify the corresponding components of the Nernst equation.

(iii) Most candidates were able to use the equation gradient = $2.303RT \div nF$ to successfully calculate a value for *n*.

Fewer candidates recognised that *n* represents the number of electrons transferred in the redox process and, as such, must be a whole number. This highlights the importance of interpreting calculated values in the context of the underlying chemistry.