CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Eleven questions were found to be easier, **questions 1**, **4**, **5**, **6**, **8**, **15**, **17**, **24**, **27**, **28** and **39**. Six questions were found to be more difficult, **questions 10**, **13**, **22**, **25**, **32** and **37**. The questions that were found to be more difficult will now be looked at in greater detail.

Comments on specific questions

Question 10

The most commonly chosen incorrect answer was **A**. The reaction pathway diagram shown in option **A** has an activation energy that is three times bigger than the enthalpy change of the reaction. The reaction pathway diagram shown in option **B** has an activation energy that is twice as big as the enthalpy change of the reaction. **B** is therefore the correct option.

Question 13

The most commonly chosen incorrect answer was **B**. Since 1.5 mol of ester has been formed, 1.5 mol of water has also been formed, giving a total of 2.5 mol of water at equilibrium. 1.5 mol of ROH, and 0.5 mol of ethanoic acid are also present at equilibrium, since 1.5 mol of each has reacted. Therefore $K_c = (1.5 \times 2.5) \div (1.5 \times 0.5)$, which equals 5.00.

Question 22

The most commonly chosen incorrect answer was **A**. The correct answer cannot be **A**, barium bromide as it reacts with dilute sulfuric acid to form a precipitate of barium sulfate. Substance **C**, magnesium bromide, does not react with dilute sulfuric acid as magnesium sulfate is soluble in water. Magnesium bromide does react with silver nitrate to give a precipitate that is partially soluble in aqueous ammonia.

Question 25

The most commonly chosen incorrect answer was **A**. 3-methylcyclobutene has no geometric isomers, but it has one chiral carbon atom, so there are two stereoisomers. When HBr adds to 3-methylcyclobutene the bromine atom may go on carbon atom 1 or on carbon atom 2. When it goes on carbon atom 1 there are two isomers, one with the bromine atom and the methyl group both on the same side of the plane of the ring, and one with the bromine atom and the methyl group on different sides of the plane of the ring. When it goes on carbon atom 2 there are four isomers:

1. one with the bromine atom and the methyl group both above the plane of the ring
2. one with the bromine atom and the methyl group both below the plane of the ring
3. one with the bromine atom above the plane of the ring and the methyl group below the plane of the ring
4. one with the bromine atom below the plane of the ring and the methyl group above the plane of the ring.

Question 32

The most commonly chosen incorrect answer was **C**. Compound **C** produces three isomeric alkenes, as dehydration can occur across each of the three C–C bonds adjacent to the –OH group. Compound **C** produces only one alkene product, as there is only one C–C bond adjacent to the –OH group.

Question 37

The most commonly chosen incorrect answer was **B**. This corresponds to rows 1 and 3 of the table. Row 1 is not a possible answer as compound P, pentanoic acid, has been reduced to compound Q, butan-1-ol. This cannot be achieved by $LiAlH_4$, which will reduce pentanoic acid to pentan-1-ol.

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Paper 9701/12
Multiple Choice

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

General comments

Five questions were found to be more difficult. **Questions 4**, **16**, **22**, **26** and **40**. These questions will now be looked at in greater detail.

Comments on specific questions

Question 4

The most commonly chosen incorrect answer was **B**. For most candidates, this question rested on pair 4 and whether or not Cl^+ and O are free radicals. A free radical is a species with one or more unpaired electrons. Both Cl^+ and O have two unpaired electrons, so the correct option is **A**.

Question 16

The most commonly chosen incorrect answer was **A**. This is incorrect as aluminium chloride does not have a giant ionic lattice as described in the question. **D** is correct as phosphorous(V) chloride hydrolyses when it is added to water, producing a solution containing ions. These ions include H^+ ions and Cl^- ions. Therefore, the solution produced when phosphorous(V) chloride is added to water conducts electricity, and the correct option is **D**.

Question 22

The most commonly chosen incorrect answer was **A**. Candidates may have been put off the correct response, **D** because one of the four bonds may be drawn as a dative bond. However, once the ammonium ion has formed each of the four N–H covalent bonds, each consists of one shared electron pair, therefore are effectively identical to each other.

Question 26

The most commonly chosen incorrect answer was **A**. The first step to solve this is to use the density of 3.50×10^{-3} g cm^{-3} to calculate the M_r of Z using the molar volume of gas. $3.50 \times 10^{-3} \times 24\,000$ is 84, so this is the M_r of Z.

Z is therefore an isomer with the molecular formula C_6H_{12}. With 2,3-dimethylbut-2-ene this would produce propanone when it reacts with an excess of hot concentrated acidified $KMnO_4$. Hex-2-ene produces a mixture of ethanoic acid and butanoic acid. Hex-3-ene produces propanoic acid only, so the key is **D**.

Question 40

The most commonly chosen incorrect answer was **D**. The absorption at 1700 cm^{-1} and the deep and broad absorption between 2500 and 3200 cm^{-1} shows the presence of a –COOH group. Compound Y is therefore a carboxylic acid. This may explain why many candidates chose option **D**. However, the question asks for the identity of compound X, not compound Y. Compound X is oxidised by acidified $K_2Cr_2O_7$ to produce carboxylic acid Y, so compound X must be a primary alcohol, so the correct option is **A**.

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Paper 9701/13
Multiple Choice

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

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

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

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

General comments

Five questions were found to be more difficult. **Questions 6**, **13**, **28**, **29** and **35**. The questions that were found to be more difficult will now be looked at in greater detail.

Comments on specific questions

Question 6

The most commonly chosen incorrect answer was **C**. It can be deduced from this that the majority of candidates were able to conclude that borazole is planar. One borazole molecule has three double bonds. Each double bond consists of one σ bond and one π bond. Each π bond consists of two electrons, rather than one, so there are six electrons in total so the correct option is **D** not **C**.

Question 13

The most commonly chosen incorrect answers were **A** and **C**. The oxidation number of nitrogen in HNO_2 is +3. In HNO_3, +5 and in NO, +2. Therefore, when one mole of HNO_2 reacts to produce one mole of HNO_3 each nitrogen atom is oxidised from +3 to +5. This must be accompanied by two moles of HNO_2 being reduced to two moles of NO, so that the change in oxidation numbers adds up to zero: (+2–1–1=0). From this we can deduce W is 3, U is 1 and V is 2. The equation for the reaction is $3HNO_2 \rightarrow HNO_3 + 2NO + H_2O$.

Question 28

The most commonly chosen incorrect answer was **B**. It would be correct if this reaction proceeded by the S_N1 mechanism. Tertiary halogenoalkanes react with OH^- ions by the S_N1 mechanism. However, the 1-bromobutane identified in the question is a primary halogenoalkane. Primary halogenoalkanes react with OH^- ions by the S_N2 mechanism. Option **A** describes this S_N2 mechanism correctly.

Question 29

The most commonly chosen incorrect answer was **A**. But-2-ene reacts with cold dilute acidified $KMnO_4$ to give butan-2,3-diol; this is X. But-2-ene reacts with hot concentrated acidified $KMnO_4$ to give ethanoic acid; this is Y. In the four options, the only correct statement about X and Y is that both compounds react with sodium metal, so the correct option is **C**.

Question 35

The most commonly chosen incorrect answer was **D**. Ethanoic acid reacts with lithium aluminium hydride to give ethanol as the organic product. The M_r of ethanol is 46. Ethanoic acid reacts with magnesium to give magnesium ethanoate, $Mg(CH_3COO)_2$ as the organic product. The M_r of magnesium ethanoate is 142.3. Ethanoic acid reacts with potassium carbonate to give potassium ethanoate, KCH_3COO, as the organic product. The M_r of potassium ethanoate is 98.1. Ethanoic acid reacts with propan-2-ol to give 1-methylethylethanoate, $CH_3COOCH(CH_3)_2$, as the organic product. The M_r of 1-methylethylethanoate is 102.

142.3 is the highest M_r value, so the correct option is **B**.

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Paper 9701/21
AS Level Structured Questions

Key messages

- Candidates are reminded of the importance of reading questions carefully and checking that their answers have covered what is required in the question.
- The use of correct chemical vocabulary is crucial to answering certain questions to demonstrate that the candidate understands the concepts being tested in the questions.
- Basic chemical formulae needs some attention, for example, the chemical formula of oxygen is O_2, boron is B and iron is Fe.

General comments

The majority of candidates attempted all of the questions.

Comments on specific questions

Question 1

(a) The colour of the halogens (at 293 K) was not often answered correctly by candidates. Common errors included chlorine described as yellow and iodine as a purple gas. Several candidates gave the colours of silver halides.

(b) The volatility of the halogens chlorine, bromine and iodine is associated specifically with the increased strength of the instantaneous dipole-induced dipole forces between the molecules due to the increase in the number of electrons in these molecules. Many candidates correctly stated that the volatility decreases from chlorine to bromine to iodine. This trend was then incorrectly attributed or linked to the electronegativity variations of the elements or the attraction between the nucleus and the outer electrons.

(c) (i) The majority of candidates used the full formula equation rather than ionic for the reaction of bromine with sodium iodide. Many answers included the spectator ion Na^+ in the equation.

(ii) It was recognised by several candidates that bromine, when reacted with sodium iodide, behaved as an oxidising agent to form iodine and a bromide. Many explanations then incorrectly referred to a change in oxidation number, or movement of electrons, in iodine instead of the iodide ions.

(d) (i) Many candidates gave a correct equation for the reaction of NaBr with concentrated sulfuric acid. Common errors were $NaSO_4$, for sodium sulfate(VI).

(ii) Candidates often identified $NaCl$ as the salt that produced the largest percentage of hydrogen halide. The explanations frequently referred to the reactivity of the sodium halides instead of describing the trend in the hydrogen halides or halide ions as reducing agents.

The most common incorrect answers identified ‘sodium iodide’ producing the largest percentage yield of hydrogen halide as ‘it is the most reactive’.

Question 2

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

(ii) The majority of answers gave a formula for the different Period 3 element when the question asked for a name. Common errors included phosphorus chloride, omitting the oxidation number, and phosphorus pentachloride, which is a solid.

(b) (i) The dot-and-cross diagram of SCl_2 was well answered. A common error included annotating the electrons around the S atom as 'x' in contradiction of the rubric.

(ii) The VSEPR theory was not well known when applied to a central S atom with two bonding pairs and two lone pairs of electrons in the outer shell. The majority of candidates focused on the two bonding pairs in SCl_2, stating that the shape was linear with a bond angle of 180°.

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

(ii) Most candidates gave a correct equation for the reaction of magnesium nitride with water. The most common error was an incorrect formula for magnesium nitride and magnesium hydroxide given as MgOH or MgO.

(iii) The marks were awarded to a minority of candidates. Very few candidates stated that hydroxide ions were present either from the dissociation of $Mg(OH)_2$ in solution, or from a reaction between ammonia and water.

(d) (i) The empirical formula of boron nitride was well answered with a common error of Br used to represent boron.

(ii) Many candidates gave the correct answer of graphite that has a structure similar to that of boron nitride. SiO_2 and graphene were common incorrect answers.

Question 3

(a) Defining Le Chatelier's principle proved challenging for some candidates with a common answer being a definition of a dynamic equilibrium, in terms of the rates of forward and backward reactions. A further error referred to a shifting of the system rather than of the equilibrium, following a change in conditions.

(b) Many candidates were able to deduce the directed changes to an equilibrium subjected to a change in temperature. The most common incorrect answer was 'no change' for the effect of temperature change on the numerical value of K_c, the equilibrium constant.

(c) (i) A minority of candidates were able to calculate the initial moles of $Fe^{3+}(aq)$ in an equilibrium mixture: $Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$, where the concentrations of two species in the equilibrium mixture were provided in the question.

Some candidates correctly calculated the moles of $SCN^-(aq)$ and $FeSCN^{2+}(aq)$ at equilibrium, but then proceeded to subtract these two values instead of adding them, to give the initial moles of $Fe^{3+}(aq)$.

(ii) Many candidates were unable to calculate a correct value for the K_c, for this reaction, but gained credit for the correct units.

Question 4

(a) The majority of candidates recognised that the definition of enthalpy change of formation involved an enthalpy change for the formation of one mole of compound from its elements. Most answers omitted that the elements were required to be in their 'standard states'.

(b) (i) The award of full credit was rare. Many equations omitted the state symbols and/or gave correctly balanced equations for two moles of product. It was common to see Fe^{3+}, for Fe, and O for O_2.

(ii) The calculation of the enthalpy change for the reaction: $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ proved challenging for many candidates. The common errors included:
- use of incorrect stoichiometry
- use of an enthalpy value for the formation of Fe and
- incorrect use of enthalpy cycles.

Question 5

(a) A minority of candidates gave the correct definition for a covalent bond. The most common errors included omitting a pair of electrons (being shared) and not mentioning that the attraction, for these electrons, was between the nuclei (of the two atoms).

(b) (i) The hybridisation of each carbon, in a C=C bond, was generally well answered.

(ii) Many candidates found this question difficult; some diagrams representing a σ bond were correct showing a linear overlap of two atomic orbitals or hybrids.

The diagrams for the formation of a π bond were often incorrectly drawn.
The most common mistakes included:
- not labelling p-orbitals, involved in the π bond formation
- drawing only the 'resultant' stage of π bond formation, showing the delocalised electrons above and below the nuclei, but without any labelling.

(c) (i) Credit was rarely awarded and most answers included a statement on how the σ and π bonds are formed by linear and sideways overlap of the relevant orbitals, which was then considered to render the π bond weaker than the σ bond.

The key idea is that during an electrophilic addition reaction the electrons in the π bond are involved as they are further from the carbon nuclei in the C=C bond and thus experience a weaker force of attraction from these nuclei.

(ii) Candidates who understood the reaction usually gained full credit. The main error involved the careless drawing of arrows, which often started from a C atom instead of from the middle of the π bond or from the Br, in a Br^- ion, instead of from a lone pair on the Br^- ion.

Question 6

(a) (i) The definition of stereoisomerism was one of the least well answered questions. The most common error was to state that 'molecules had the same molecular formula but different structural formula'. Few mentioned that it was the arrangement of the atoms or groups in space.

(ii) Very few answers gained full credit here. Some candidates identified a C=C double bond and two chiral centres and then incorrectly stated that this gave $(2 \times 3 =)$ 6 stereoisomers instead of using the correct expression 2^3 (= 8).

(iii) The molecular formula of **V** was answered quite well. There were no common errors.

(iv) Many candidates correctly identified an alkene and carbonyl group. The most common error was to omit the ester group and substitute it for an alcohol group or a carboxyl/carboxylic acid group.

(b) (i) The question required an identification of the role of reagent **T**. Candidates who stated that **T** behaved as a reducing agent gained full credit. Those candidates who ventured to explain the behaviour of **T** with each functional group generally understood that it reduced the carbonyl group in **V** to an alcohol group in **W**. The reaction of the C=C to from a saturated chain attracted a variety of incorrect answers ranging from acting as a catalyst to hydrolysing the alkene group.

(ii) This question was well answered.

(c) (i) Candidates found this very challenging. Many answers used the m/e values of 200 and 201, from the mass spectrum, instead of the relative abundance values of 100 and x, and attempted to average these values to determine the relative atomic mass.

Creditworthy answers deduced that **Q** contained 12 C atoms and then used this value of *n* in the expression $n = \dfrac{100 \times \text{abundance of M} + 1\text{ ion}}{1.1 \times \text{abundance of M} + \text{ion}}$

to calculate the abundance of the (M + 1) ion which is equivalent to the value of x.

(ii) This question was answered correctly by many candidates with the most common error being to omit ‘precipitate’ with the orange colour for the observation with 2,4-DNPH with **Y**.

(iii) The majority of candidates did not recognise that the volume of hydrogen gas was collected at s.t.p., in the question, which, from the Table of data, is $22.4\,\text{dm}^3\,\text{mol}^{-1}$.

Various methods were used to calculate the moles of gas produced to include the ideal gas equation and $24.0\,\text{dm}^3\,\text{mol}^{-1}$.

Those candidates who managed to calculate the number of moles of gas then needed to appreciate that the ratio of hydroxyl groups to hydrogen gas was 2 : 1. The award of full credit was rare.

(iv) Many candidates gave correct absorption ranges for one of the two carbonyl absorptions in **Y**, for the ketone and ester functional groups. Several answers gave a range of absorptions for a carboxyl group in **Q** as a difference in the infrared spectrum, having not appreciated that **Q** contains **only** hydroxyl groups, mentioned in the stem of **(c)(ii)**.

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Paper 9701/22
Structured Questions

Key messages

- Candidates should be encouraged to learn accurately the basic details and definitions as specified by the syllabus. Diagrams should be practised so they can be presented concisely and without ambiguity.
- In questions which involve an application of knowledge, candidates are expected to engage with the information provided.

General comments

The use of intermediate values to too few significant figures produced inaccuracy in the final answer, even when this was given to the appropriate number of significant figures.

Chemical equations should always be balanced.

Comments on specific questions

Question 1

(a) The majority of answers were correct.

(b) Some excellent explanations were seen. Occasionally the aluminium ion was incorrectly described as larger than the magnesium ion. In general, the explanations focussed, at least in part, on the difference in nuclear attraction which arises as a result of the difference in nuclear charge and the same shielding effect of both species.

(c) Clearly labelled diagrams, which showed a regular arrangement of sodium cations surrounded by delocalised electrons, were seen in a significant proportion of answers. Poorer diagrams showed randomly placed positive ions or made no reference to ‘delocalised’ electrons. Occasionally, the positive symbols were described incorrectly as ‘nuclei’ or ‘protons’ or ‘atoms’.

(d) (i) The majority identified the structure and bonding present in silicon. A much smaller proportion used this knowledge to explain why silicon had a high melting point in terms of the high energy requirement required to break many strong covalent bonds. A common misconception described intermolecular forces in a giant molecular structure.

(ii) Of those that annotated Fig.1.1, many correctly compared the melting points of P, S and C*l* with those of the three metals provided. Comparison of the melting points between P, S and C*l* was less well known.

(e) (i) This question proved to be demanding. The state of both sodium oxide and sulfur dioxide under room conditions was not well known. Misunderstanding of the term ‘state of oxide’ and oxidation number was seen on occasions. A common misconception described aqueous solutions of sodium oxide with a pH of 7.

(ii) Correct identification of this reaction as acid–base or neutralisation was common.

(iii) The product for the reaction of P_4O_{10} with an excess of water was well known. Equations were not always balanced.

(f) (i) The majority of answers demonstrated a good understanding of the term amphoteric.

(ii) There was some confusion with this reaction and the reaction of aluminium oxide and sodium hydroxide. The correct formula of the product was not well known.

Question 2

(a) Appropriate profiles for an endothermic reaction were common. In general, representation of activation energy and enthalpy change were correct. Some answers showed very imprecise location of arrows on the diagram or showed arrows which did not point in the correct direction.

(b) (i) Good answers described an appropriate observation based on the idea that no more gas is produced when the reaction stops.

(ii) This calculation proved to be demanding. The specific heat capacity of water was not always given to the appropriate number of significant figures. The step to convert the amount of energy produced in the experiment to the amount of energy produced per mol was often confused. A significant proportion of answers included a negative sign for the enthalpy change value to reflect the exothermic nature of the reaction. Some answers were given in terms of J mol^{-1} rather than kJ mol^{-1}, as directed in the question.

(iii) The best answers showed a correct Hess' cycle in their working. Weaker responses tended to use appropriate stoichiometry in their calculation but confused the algebraic relationship between ΔH_1 and ΔH_r in the calculation. A relatively high proportion of candidates did not attempt to answer this question.

(c) Many answers deduced that **Z** was a Group 2 nitrate. Identification of calcium as a Period 4 element presented some difficulties and $Sr(NO_3)_2$ was seen on occasions. Production of the balanced equation for this thermal decomposition proved to be demanding.
The weakest responses identified the brown gas as bromine and gave equations of Group 2 bromides producing bromine.

Question 3

(a) Accurate descriptions of this definition were seen. Some weak responses were vague and incomplete, e.g., 'when forward and backward reaction is equal'. The misconception that dynamic equilibrium occurs only when 'concentration of reactants and products are the same' was also seen.

(b) (i) This question proved to be challenging. Many candidates were unable to apply le Chatelier's principle to this novel equilibrium reaction.

(ii) Some excellent answers, presented clearly and logically, were seen in this demanding question. A significant proportion of candidates confused the terms 'amounts' and 'concentrations'. Understanding of the different mathematical relationship between 2x and x^2 was not always appreciated. Correct deduction of the unit was common.

(c) Many answers were not based on the knowledge that 4s electrons are lost before 3d electrons when the electronic configuration of a transition metal cation is described.

(d) Correct dot-and-cross diagrams were seen. Weaker responses showed correct bonding electron arrangement and ignored the additional electron present in a SCN^- anion.

Question 4

(a) Some excellent representations of the three-dimensional structures were seen; these included the approximate bond angles for these tetrahedral structures. Other diagrams showed confusion over the types of symbols used to represent bonds in the plane with those in and out of the plane. In order to remove ambiguity, candidates should be encouraged to use the convention described in the syllabus, under expected conventions for representing organic structures.

(b) Good knowledge of the S_N1 mechanism was described with precision in the best answers. Some confusion regarding the relative charges on the C–Br dipole and either no reference to a lone pair of electrons on O of OH^- or the location of the lone pair of electrons on the H of OH^- were common incorrect details. Some answers confused the S_N2 mechanism details with S_N1.

(c) The observations of these reactions were generally well known. Some answers did not include observations, as directed in the table heading, rather than attempted to predict the product of the reactions.

(d) (i) The name of this reaction was quite well known. Addition, substitution, dehydration and cracking were common incorrect answers.

(ii) The reagent NaOH was described in many answers. Confusion of the relevant conditions was seen in weaker responses.

(e) (i) Fully correct answers were seen in around half of responses. Sometimes confusion between two of the types of hybridisations was seen. The weakest answers demonstrated a lack of understanding of the different types of hybridisations which occur in carbon atoms in order to produce single, double and triple covalent bonds.

(ii) It was common for answers to contain features which lead to both types of stereoisomerism rather than focus on the stereoisomerism present in unbranched hydrocarbons. A relatively small proportion of answers showed good understanding of the features of an alkene required in order for it to exist as geometrical (cis/trans) isomers. A lack of precision in answers produced some ambiguity in responses, for example ‘no movement of a double bond’ rather than ‘no rotation of a double bond’.

Question 5

(a) (i) Those candidates with a good understanding of mass spectrometry realised that the peaks shown in Table 5.1 represented the molecular ion peak, M^+, and its $(M+1)^+$ peak and used the appropriate formula to calculate the relative abundance of the M+1 peak. Some weaker responses based their calculation on an incorrect formula.

(ii) The strongest responses engaged with the information about compound **W**. Weaker responses did not engage fully with the question details and answered in terms of structural formulae. Some formulae gave the fragments with no charges or negative charges.

(b) (i) An understanding that an O–H bond, due to a carboxyl functional group, produces a broad stretch within the range 2500–3000 cm^{-1} was seen in the best responses. The weakest responses did not engage with the details given for compound **W** and its reaction to produce **X**, and listed every potential functional group which might account for bond **A** and bond **B**, including amide and ester functional groups.

(ii) Of those candidates that correctly identified **B** as a C=O of a carbonyl group, some candidates ignored the reaction conditions stated in the question and represented **X** as an aldehyde rather than a ketone.

(c) (i) A significant proportion of candidates correctly named the functional group present in **Y**, based on the information provided.

(ii) Many equations were shown with the correct formula of the organic product; not all equations were balanced. Identification of H_2O rather than H_2 as the other product was seen.

(iii) Those candidates who applied knowledge of the behaviour of different types of alcohol and carbonyl compounds correctly deduced the structure of **Y**. Confusion about the chemical reactions of alcohols and carbonyl compounds was seen in weaker responses.

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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, linking structural features to mechanistic probabilities.

- Working in calculations should be 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 answer both knowledge and understanding (AO1) type items and handling, applying and evaluating information (AO2) items, though items which assessed AO1 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, particular in the placement of the origin and destination of curly arrows: candidates can often lose marks through imprecision whereas their underlying knowledge may not in fact be deficient.

Comments on specific questions

Question 1

This question assessed inorganic chemistry, with some aspects of physical chemistry. This tested principally in the AO1 category. Candidates showed some facility of recall but were equally divided in response when asked to apply their knowledge to unfamiliar circumstances.

(a)(i) This standard recall question could be answered with easy reference to syllabus points.

(ii) With reference to the syllabus, orbital overlap can be directly quoted; knowledge of the bonding in N_2 is also straightforward, so the number of σ and π bonds should be readily accessible.

(b)(i) Many candidates answered this question well.

(ii) This question gave rise to many variations of answer. Candidates are advised to be brief with their answers: often, correct responses were contradicted by (incorrect) explanations of valence electrons.

(c)(i) Many candidates answered this question well.

(ii) The reaction of P_4O_{10} was better known than that of Al_2O_3. The latter is not less common but requires better honed balancing skills if constructed rather than written in recall.

(d)(i) Many candidates answered this question well.

(ii) Many candidates were able to identify the type of reaction that occurs.

Question 2

Although **(d)** focused on inorganic chemistry, the majority of this question was based on equilibria and rates. Better performing candidates were able to discern the differing aspects here: rates and collision theory formed one notion; equilibria, yield and Le Chatelier’s principle the other.

(a) This was generally well answered, with many candidates identifying the null effect of a catalyst on equilibrium position. The best answers stated this explicitly.

(b)(i) This was well answered by candidates, who could link lower yield with the exothermic reaction. Precision of wording was key here.

(ii) Many candidates attempted to answer this rates question in terms of equilibrium yield and were unable to gain full credit as a result. If an item pairs rate and yield within a question, candidates are advised to read the stem of the question carefully and to give relevant answers.

(c)(i) Many candidates were unable sufficiently to distinguish between K_c and K_p. Square brackets must not be used in K_p expressions to avoid confusion with concentration variables. Partial pressure variables can be given as p_X, P_X, $p(X)$, $P(X)$ or $pp(X)$.

(ii) Many numerical answers were correct, though common errors included not adjusting the equilibrium concentrations of N_2 and H_2, or not accounting for $\mathbf{2}NH_3$ or $\mathbf{3}H_2$ in the stoichiometric equation.

(iii) This was generally well answered by candidates, although some errors of powers of ten were seen in a minority of responses.

(d)(i) Candidates’ knowledge of this nitrogen chemistry seemed largely secure, though correct quotation of three equations (two showing NO_2 catalysis and one of the conversion of SO_3 to acid rain) were needed to gain full credit, alongside a statement of the role of NO_x.

(ii) There were many good partial answers to this question, with most referring to PAN but with less precision on how this is produced.

Question 3

Candidates are urged to look carefully at the information provided in each item: here, this proved helpful and key to answering the ensuing physical chemistry questions.

(a) This was well answered by candidates. Standard states were required, that of water being (l).

(b) Common errors included incorrect stoichiometry or reverse parity for the answer. On the whole, the principle of Hess's Law seemed to be understood where answered.

(c)(i) There were very many different answers here; it seemed that candidates were supposing that the reaction of 'metallic' boron and non-metallic carbon must result in a giant ionic lattice.

(ii) This was well answered by candidates who correctly used the A_r values of B and C. Some confusion was evident over the method of deciding the ratio of B : C. Answers without working were not credited, nor were answers trying to reason a formula from the ratio of putative charges of ions.

Question 4

Many individual parts of this question were answered well. Parts **(a)**, **(c)(i)**, **(e)(ii)** and **(f)(ii)** were clearly the most challenging, often as candidates were required to apply several independent parts of their knowledge of the syllabus.

(a) Candidates were not strictly required to give dot-and-cross diagrams, though these and modified Lewis diagrams often produced the clearest responses. Many answers incorrectly showed a pentavalent nitrogen atom — a kind of NH_5 species, with little understanding of the NH_4^+ Cl^- superstructure. The dative bond needed to be clearly distinct from other covalent bonds and ionic charges needed to be given.

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

(ii) Different versions of this answer were offered, but a large number were a simple addition of NH_4^+ and OH^-, which did not gain credit.

(c)(i) This was well answered by candidates whose knowledge extended to terminology associated with electron-pair donors.

(ii) This was found to be the most challenging item on the paper which required candidates to assess either the basicity or nucleophilicity of each species. Opposing answers were therefore acceptable with enough reasoning.

(d) This was generally well answered by candidates, but the single-step nature of the S_N2 mechanism needed to be clearly evidenced by one transition state; the slower rate of this reaction by a higher energy of the TS relative to either produced in S_N1. Candidates frequently accessed the former part but often then erroneously showed some kind of catalysed reaction with a lower activation energy.

(e)(i) This question was not generally well answered, as candidates were not able to associate electron movement with the correct stage of the reaction and often were very imprecise with their positioning of curly arrows. Many answers had the arrowhead and tail reversed, with a lot of responses suggesting electron movement *from* extra H^+ species.

(ii) This question was reasonably well answered.

(iii) This question was generally well answered, although stray vowels or unspecific/incorrect numbering were observed. Candidates are reminded that the longest carbon chain is the important root of a molecule's name.

(f) (i) Candidates were able to provide a correct answer here by analogy of the 2-bromobutylium species on the left-hand side.

(ii) This was found to be a demanding question, although candidates who recognised the necessary reference to the stability of the intermediate were able to give a reasonably straightforward AO1 account for full credit.

Question 5

This question tested organic reactions and spectroscopic methods using cyclohexene as a starting material. Many candidates seemed familiar with the chemistry, although the context of a cyclic molecule proved to be disconcerting for a few, who appeared to misinterpret the information given, or did not concentrate solely on the relevant functional groups.

(a) This was well answered by many, although differences appeared in the conditions to use with the $KMnO_4$ reagent (e.g. concentrated/dilute, alkaline/neutral/acidic).

(b)(i) Step 1 was familiar to many candidates. The hydrolysis of two functional groups in step 2 led many to think that H_2O_2 was being used, rather than two portions of NaOH.

(ii) In asking for a mechanism, ‘electrophilic’ was expected as well as ‘addition’.

(c) Candidates showed some understanding in answering this question but often missed full credit by not following the rubric properly: the diagram needed labelling and each responsible bond (stretch) needed to be clearly identified. Many candidates only achieved half of this, or switched **F** and **G**.

(d)(i) This was mostly well answered, although some candidates lost credit when opting to give fully displayed versions of the CN group, neglecting to show a triple $C{\equiv}N$ bond or using the wrong connectivity (N attached to the ring).

(ii) This was answered well by many candidates. Others did not acknowledge that acidic conditions are used, creating an ammonium species rather than NH_3.

(iii) The formulae of the organic products were generally well indicated, though candidates often then misbalanced the equation with insufficient (H).

(iv) This was generally well answered by candidates. A few $NaBH_4$ responses were offered, to no credit: carboxylic acids need the stronger of the two hydride reagents on the syllabus.

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 the full name or correct formula to describe any reagent selected for use in a test
- 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
- ensure their answers, particularly numbers, are clearly legible with errors crossed out rather than being written over the top of previous attempts.

General comments

This paper generated a wide range of marks.

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.

Supervisor results for both the quantitative and qualitative tasks 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 results are comparable 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.

Larger centres with several different supervisor results relating to different laboratories and sessions are requested to ensure that all candidate and supervisor scripts are correctly labelled with these details on the front cover so that each candidate's results are assessed against the correct supervisor's results.

Centres are reminded that the descriptions of solutions on the question paper are **not** always the same as the solutions provided to the candidates as instructed in the Confidential Instructions. Candidates must assume that the information given in the question paper is correct.

Comments on specific questions

Question 1

Candidates generally seemed well prepared to carry out both experiments with most of them recording a temperature rise and drop close to the expected values. The processing of results proved to be more challenging for most candidates.

(a) Candidates should be reminded to check the instructions carefully to ensure that the data recorded matches that required by the question. Although this part was generally well answered, some candidates missed data. A small number of candidates gave incorrect units with 'C°' being one of the more common errors.

(b) **(i)** This calculation was completed correctly by the majority of candidates. Amongst the more common errors was the use of 4.2 rather than 4.18 and the use of the mass of only one of the two solutions mixed in the experiment.

(ii) The most common answer was 0.040. Very few candidates realised that not all the sulfuric acid reacts because it is in excess.

(iii) Candidates generally did better on **(iii)** compared to **(ii)** with many correctly combining their previous answers. Most candidates correctly used a negative sign for the enthalpy change when a temperature rise is recorded. Candidates should be reminded that the energy produced is usually recorded in joules whereas the enthalpy change is usually recorded in kilojoules per mole so a division by 1000 is required.

(c) Amongst the more common recording errors was the omission of one or more units and insufficient clarity regarding the mass of the container with and without **FA 3**.

(d) Nearly all candidates gave a correct combination of their values for energy and number of moles. Slightly fewer candidates gained credit for calculating the energy because an incorrect mass value was used. Most candidates used an incorrect value of 0.05 for the number of moles of sulfuric acid meaning that only the higher performing candidates gained full credit.

(e) The introduction of ΔH_3 proved to be too demanding for most candidates with very few being able to construct a correct Hess's cycle.

(f) This question illustrated the importance of carefully reading all the information provided. Most candidate responses ignored the fact that the sulfuric acid is in excess.

Question 2

(a) The general quality of the recording of titration data was high with most candidates meeting the standard required in terms of table layout, units, precision and data concordance. Centres should remind their candidates that the values used to calculate the rough titre must be recorded either in the space provided or in their data table, if clearly labelled as 'rough'. The results seen in candidate responses suggest that some centres would benefit from greater familiarity with the iodine thiosulfate titration. Data was frequently spread over a wide range with little or no agreement between the supervisor and the candidates.

(b) This was generally answered well although candidates should be reminded that the values used for the mean should have a maximum range of $0.20\,cm^3$.

(c) **(i)** The requirement to give answers to a correct number of significant figures was generally well understood. However, some candidates did not include trailing zeroes where required.

(ii) Whilst many candidates realised that 14.24 ÷ 158.2 was part of the calculation required, very few went on to combine this with their titre value to get the correct final answer. Candidates should be reminded to use the relative atomic mass values given to one decimal place in the Periodic Table provided.

(iii) Although some candidates noted the 1 : 2 mole ratio, most struggled with this calculation.

(iv) Although 0.06 was often seen as part of the working, very few candidates answered this correctly.

(v) Candidates performed a little higher here by correctly combining their answer to **(iv)** with the mass of sodium sulfite used.

(vi) For questions involving the calculation of *x* in the formula of a hydrated for salt, candidates should be reminded that the required answer will usually be an integer. This guidance is usually stated somewhere in the question if candidates are unsure.

In summary, this calculation proved to be very challenging for the majority of candidates. Centres should be encouraged to familiarise candidates with this type of calculation involving solutions that are partly reacted with the resulting solution then being used in a titration.

Question 3

Candidates should be encouraged to refer to the Qualitative analysis notes towards the end of the paper. Not only do these notes help with the identification of samples but they also provide a model for how certain observations should be recorded.

(a) (i) Many candidates were able to make and record sufficient observations to reach a correct conclusion. The reactions of **FA 8** and **FA 9** with magnesium were correctly recorded by most candidates although fewer responses noted the difference in reaction rate. Candidates generally did less well with **FA 7** where the reaction was not immediate. Many candidates also omitted a positive gas test for hydrogen with **FA 8** and **FA 9**.

(ii) The fact that ethanoic acid was used seemed to confuse many candidates with only the higher performing candidates realising that the ionic equation for the production of hydrogen gas is the same regardless of the acid used.

(b) (i) Most candidates gained at least some credit available although it was quite rare to see candidates gaining full credit. Centres should remind candidates to clearly and unambiguously record the effect of using excess reagent when doing the cation tests. When testing for ammonia, it is important that candidates make it clear that it is the gas rather than the solution that is responsible for turning the damp red litmus paper blue.

(ii) Many candidates did not use the prompt in the question regarding what to record if no clear conclusion can be made, so very few candidates concluded that the anion present in **FA 11** could either be nitrite or nitrate.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

Candidates with experience of practical chemistry tended to do well in this paper. Candidates are encouraged to:

- read the questions carefully and prepare tables for recording data before commencing practical work
- pay attention to the precision of the data being recorded and quote figures to the appropriate number of significant figures
- use the periodic table and Qualitative analysis notes in the question paper
- present results clearly and using the correct terminology.

The supervisor results are vital to enable the awarding of credit for the quality of the results candidates produce.

General comments

Candidates should note that where tables of data need to be prepared and recorded, as in **Questions 1(a)** and **2(a)**, the data should be recorded in the space provided. Candidates should be careful to present their data clearly and unambiguously – corrections should be made by crossing out the incorrect work and writing the correct work next to it. Candidates should not write a correct answer over an incorrect answer. Working in pencil and then writing over work in ink can make the response difficult to read.

Most centres made up the solutions correctly according to the Confidential Instructions, but centres should note that the composition of solutions given to candidates does not always match the information in the paper; this is quite deliberate and solutions should always be prepared and labelled for candidates using information in the Confidential Instructions.

Comments on specific questions

Question 1

This question required candidates to calculate the enthalpy of formation of the pentahydrate of sodium thiosulfate from the anhydrous salt and water. Most candidates were able to conduct the experiment and gain credit for valid results, then go on to calculate the enthalpy change correctly. Far fewer could deduce the answers to questions relating to the method.

(a) Candidates found this question challenging. The proposed method would not be valid for a variety of reasons which candidates struggled to identify. It would be difficult to measure a temperature change of a solid and it would be unlikely that the proposed experiment would result in a uniform sample of the pentahydrate. Some candidates correctly suspected that some of the solid would simply dissolve.

(b) The clear instructions were followed by almost all candidates to generate good results with a drop in temperature. Almost all candidates constructed a table for their results in the correct space on the paper. Headings for data were accurate although the error of giving the 'final temperature of water' was seen occasionally – the final temperature recorded is that of a solution. The correct precision of the results was most often seen although some centres recorded temperatures to two decimal places, or to none at all. The subtractions necessary to obtain the mass used and the temperature change were in almost all cases correct.

It was clear that some candidates were conducting the experiment before constructing a table for results. This should be discouraged.

Credit for accuracy took into account the lack of precision possible in a small temperature change and most candidates gained credit against the supervisor values.

(c) (i) Most candidates could calculate the energy change correctly here. The most common errors were to use either the mass of the solid, the mass of solid and solution or the use of 4.2 as the specific heat capacity of water, rather than $4.18\,\text{J}\,\text{K}^{-1}\,\text{g}^{-1}$. A small number of candidates added 273 to the temperature change, thinking they were converting into Kelvin.

(ii) Almost all candidates managed to use their value from **(c)(i)** to calculate ΔH_2 correctly and showed clear working. The most common error was using 248 as the M_r rather than 248.2. Candidates are encouraged to use the values for A_r from the periodic table in the paper to calculate M_r. The sign of the final value is important here as the drop in temperature signified an endothermic reaction with a positive value for ΔH_2 and most candidates saw this.

(iii) Candidates were asked to construct a labelled Hess's cycle and were given the equation for ΔH_1 as a starting point. A good proportion of the cohort were able to do this but some did not label their energy changes or had their arrows the wrong way round. The value for ΔH_3 was given and almost all candidates used it to calculate a value for ΔH_1. Many candidates obtained a correct answer but often they had signs reversed.

(d) This question looked at the effect of a contaminant on the temperature change of the conducted experiment. Candidates were expected to see that the reaction of the contaminant with water was exothermic (shown by the negative value for ΔH_3 in **(c)(iii)**) and so there would be less of a temperature drop. A good number of candidates stated this clearly. Common errors were to refer to 'the effect on the final temperature' rather than the temperature change, or to simply state that 'with less of the hydrated solid present, the temperature change would be lower', which although correct does not use all the information provided.

Question 2

This used titration to deduce the value of x of a sodium iodate salt, NaIO_x. The concentration of the solution of IO_x^- was given and the candidates were told addition of iodide ions, in acid conditions, would liberate iodine. The iodine was then titrated against a sodium thiosulfate solution of known concentration. The key to understanding why the method works is to see that this is a redox reaction and the value of x determines the oxidation state of the iodine in the IO_x^-, which then determines the amount of I_2 released in the reaction with iodide.

(a) The titration was generally well done. Centres are practised at preparing candidates and they were able to give rough burette readings and accurate burette readings in the right places, to the correct precision and in correctly labelled tables. Some centres obtained less accurate supervisor results and candidate-derived means were used to judge accuracy marks. Centres should be advised that once concordance has been obtained (two titres within $0.10\,\text{cm}^3$), candidates should stop titrating and move on to the calculations, even if this means only two accurate titres were recorded.

(b) Most candidates could generate a correct mean titre from their data. The most common errors were using the rough titre in their calculation, using titre data with too great a spread of values (and far from concordant) and not using the correct number of decimal places (two) in their answer.

(c) (i) Credit was awarded for the precision of the answers in the subsequent questions. Candidates clearly read the question and some noted '3 sf' before moving on. The precision of the mean titre justified this level of precision and almost all candidates correctly gave their answer to **(c)(ii)** to 3 or 4 significant figures. However, many then went on to give their answer to **(c)(iii)** to only 2 significant figures and so were not awarded credit for **(c)(i)**. Almost all candidates who obtained a value for *x* in **(c)(iv)** expressed it correctly as an integer.

(ii) Many candidates could calculate the amount of iodine formed correctly, although a common error was to miss the division by 2 due to the stoichiometry of the reaction of iodine with sodium thiosulfate.

(iii) Almost all candidates correctly calculated the amount of IO_x^- in the original 25.0 cm^3 sample of **FB 3**.

(iv) About half the candidates were able to see they had calculated amounts of IO_x^- and I_2 in the previous questions and just needed to divide one by the other to provide the stoichiometric ratio between them in the equation. Those that calculated the ratio correctly came to the correct value of 3 for *x*. A common error in **(c)(ii)** led to a value of 6 for *x*.

With a value for *x*, candidates could then go on to balance the equation and many correct answers were seen. A few candidates did not appreciate the need to balance the charges on each side of the equation and so did not gain credit.

(d) Candidates found **(d)** difficult. They were asked to predict the effect of using IO_2^- ions in place of **FB 3** on the volume of **FB 2** added in the titration. Candidates should have had a value of *x* greater than 2 in **(c)(iv)** and should have seen that a lower value of *x* meant a lower oxidation state of iodine. This leads to a smaller change in oxidation state in the reaction and thus a lower amount of iodine liberated in the initial reaction. Some candidates were able to predict that the volume of **FB 3** would be lower as the amount of iodine liberated was less, but very few then linked their answer to the change in oxidation state.

A common error was to simply state that both ions had the same amount of iodine and so there would be no change in the volume of **FB 3**. This missed the point of the practical, even when the equation in **(c)(iv)** was correctly balanced.

Question 3

This question focused on qualitative analysis of several unknown ions. All tests were covered in the Qualitative analysis notes. Tests in **(a)** were to identify the cation and anion in solution **FB 7**. Candidates were expected to select and carry out tests in **(b)** to identify the anions in two solutions, **FB 8** and **FB 9**.

(a) (i) This consisted of three tests to determine the cation and anion in **FB 7**, a solution of zinc nitrate, $Zn(NO_3)_2$.

Test 1 was the addition of aqueous barium chloride and most candidates correctly recorded ‘no reaction’. Only a few candidates incorrectly recorded ‘no observation’ or simply put a dash, ‘–’ as their response. Candidate should be encouraged to read thoroughly the text preceding the question which sets out how to record ‘no reaction’.

Test 2 required the addition of aqueous NaOH, followed by warming and then addition of A*l* foil. Most correctly recorded a white precipitate which dissolved in excess NaOH due to the zinc cation. On warming, many recorded ‘bubbles’ and attempted to test for a gas, but there was no reaction at this point, the solution was simply boiling. On addition of A*l* foil, the reaction with the nitrate ion should have produced effervescence (of ammonia) but most candidates did not record this; although a majority did test the gas with damp red litmus paper and noted the colour change.

Test 3 was the addition of aqueous ammonia and most candidates correctly recorded a white precipitate which dissolved in excess.

(ii) The tests in **(i)** were sufficient to identify the cation as Zn^{2+} but the anion could have been either nitrate, NO_3^- or nitrite, NO_2^-. Candidates with correct observations in **(i)** were generally able to state the formulae of the ions correctly. The common incorrect answers were for the cation, with either Mg^{2+} or Al^{3+} following from incorrect observations of the solubility of the white precipitates seen in **(i)**. A few candidates stated the names of the ions when the question specifically asked for the formulae.

(iii) With knowledge of the two possible anions, candidates were asked to select a test to distinguish between them and carry it out. Almost all candidates correctly selected addition of potassium manganate(VII), $KMnO_4$. Of these, most then correctly recorded ‘no change’ and identified nitrate as the anion present. Common mistakes were the rendition of the reagent; candidates should be made aware that formulae, when used, must be correct and complete, so ‘$KmnO_4$’, ‘$KMNO_4$’ or just ‘potassium manganate’ were not correct and were not awarded credit.

(b) (i) Candidates were asked to select and carry out tests to identify the anions present in **FB 8** and **FB 9**. Candidates were informed that one of the ions was a halide and the other contained oxygen, but not nitrogen. **FB 8** contained the iodide ion and **FB 9** contained the carbonate ion.

Credit was available for the construction of a table in which to record observations and for the selection of valid reagents. Almost all candidates selected aqueous $AgNO_3$ to test for the halide ion, but many also selected a solution containing Ba^{2+} to test the other as sulfate or sulfite.

Those testing for the halide normally correctly described a yellow precipitate with **FB 8** to which they added ammonia solution where it remained insoluble. Occasionally, candidates incorrectly recorded a cream precipitate. If **FB 9** was also tested with $AgNO_3$, a precipitate should have been seen.

Those testing with an aqueous barium compound inevitably saw a white precipitate of $BaCO_3$. Thinking **FB 9** must contain sulfate or sulfite, they went on to test with an acid where the precipitate should have dissolved with lots of effervescence, giving them an indication that a carbonate was present. Unfortunately, many did not spot this and so concluded the wrong ion.

Candidates should be instructed that the reagents used must be identified correctly. If a solution of barium chloride is used, that is the reagent and must be identified by name or ‘$BaCl_2$’, not just ‘barium’ or ‘Ba^{2+}’. Similarly, if using a dilute acid as a reagent, the identity of the acid must be stated, such as ‘HCl’ or ‘H_2SO_4’.

Candidates who selected an acid as a reagent and saw effervescence gained credit if they also tested the gas released and found it to be carbon dioxide. Some candidates used the term ‘limewater turns milky’ or similar which has not been accepted as a valid observation for several years – the correct term is ‘gas forms a white precipitate (when bubbled through limewater)’.

(ii) Candidates who selected $AgNO_3$ and an acid as their reagents in **(i)** generally recorded the correct anions in **(ii)**. The most common error was the identification of sulfate from incomplete or incorrect tests in **(i)**.

(iii) Many candidates struggled to construct an ionic equation for observations made in chemical tests. Credit was given for a correctly balanced ionic equation that was derived from correct observations and had the correct state symbols. Most candidates who gained credit wrote the ionic equation for the formation of silver iodide or the reaction of the carbonate ion with H^+. A wide variety of incorrect responses were seen.

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
- 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
- ensure their answers, particularly numbers, are clearly legible – errors or rough work should be crossed out rather than being over-written with the new answer.

General comments

The supervisor results are vital to enable the awarding of credit for the quality of the results candidates produce. 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.

Centres are reminded that the descriptions of solutions on the question paper are not always the same as the solutions provided to the candidates as instructed in the Confidential Instructions. Candidates must assume that the information given in the question paper is correct.

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.

Larger centres with scripts containing several different supervisor results relating to different laboratories and sessions are requested to ensure that all candidate and supervisor scripts are correctly labelled with these details on the front cover so that each candidate’s results are assessed against the correct supervisor’s results.

This paper generated a wide range of marks with some candidates gaining credit in the quantitative questions. Candidates generally found the qualitative analysis question more demanding, though a few performed very well.

Comments on specific questions

Question 1

Candidates generally seemed to be well prepared in carrying out the procedure. All candidates found carrying out the method in **(a)** less challenging than much of the rest of the question.

(a) Some candidates omitted the burette readings for the rough titre or did not recording accurate burette readings to either #.#0 or #.#5 cm^3. A few candidates did not provide concordant titres as their final accurate titre was more than 0.10 cm^3 from any previous value. Once concordance has been achieved there is no reason to continue with further titrations. Repeated titrations serve only to waste the time available to answer other questions.

(b) Most performed well here. Common errors were not indicating the values used for the mean or use of titres with a spread greater than 0.20 cm^3.

(c) (i) Given the precision of the apparatus and the listed concentrations of the reagents, all final answers were expected to be given to 3 or 4 significant figures. Some candidates wrote this on their paper but then did not follow their own advice. Those not completing the calculation in **(c)(iv)** tended to incorrectly record 0.05 (initial amount of sodium hydroxide) as their final answer.

(ii) Almost all candidates were successful in this part.

(iii) Many candidates noted the stoichiometry shown in the equation.

(iv) While many candidates calculated the initial amount of sodium hydroxide, far fewer took the dilution factor into account when **FA 1** was prepared.

(v) Many candidates correctly used the factor of 1000 ÷ 10 when calculating the concentration of the ammonium chloride solution used to make **FA 1**. Some confused the volume used with the 25.0 cm^3 of sodium hydroxide.

(d) While more candidates selected an acidic drying agent as being unsuitable for drying ammonia gas than one of the calcium compounds, fewer gave a correct reason for their choice. Incorrect answers included that the acid would react with calcium hydroxide and that the acid would react to form salt plus water with ammonia gas. Those selecting calcium oxide as an inappropriate drying agent did not show understanding that both drying agent and gas are basic so there would be no danger of neutralisation.

Question 2

This question was more challenging for candidates than **Question 1**. Candidates should use the Qualitative analysis notes in the question paper to ensure they are using the correct values.

(a) Most candidates recorded the data needed for this question though some did not include essential balance readings. The errors included ambiguous headings, incorrectly displayed units and balance readings given to varying decimal places. It is important that candidates should use the same (preferably to 2 decimal places) balance for the measurement of both masses. Many candidates recorded their thermometer readings as integers. This is not what is expected as the thermometers are calibrated at 1 °C so should be read to the nearest #.0 or #.5 °C. However, most candidates correctly calculated the mass of **FA 4** and the temperature change in forming a solution. Even more gained credit for accuracy.

(b) (i) Many candidates used $q = mc\Delta T$ incorrectly. One common error was to use the mass of **FA 4** instead of the mass (volume) of water: the density of water (and dilute solutions) is 1.0 $g\,cm^{-3}$. Other errors were the use 4.2 for c instead of 4.18 $J\,K^{-1}\,g^{-1}$ and adding 273 to the change of temperature. Some candidates gave their answer to 5 significant figures which is not acceptable given the precision of the apparatus.

(ii) Some candidates did not check the units given in the information at the start of this part so omitted the division by 1000. However, more candidates were successful here than in **(b)(i)**.

(iii) Most candidates gaining an answer in **(b)(ii)** also gained credit here. However, some either miscalculated the relative formula mass or did not use the relative atomic masses given in the Periodic Table on question paper.

Candidates having difficulties with previous parts of the question were able to use a default value for the amount of ammonium bromide. However, the answer had to be correctly rounded, consequently some candidates using the 2.06×10^{-2} mol value were not awarded credit.

(iv) Many candidates were successful in this part. However, some used one of their balance readings instead of the mass of **FA 4** or inverted the expression if their answer in **(b)(iii)** was larger than their mass of **FA 4**.

(c) This was a higher level of demand question which was correctly answered by candidates who were already performing well in other parts of the paper. Common errors were to assume the temperature of the solution would increase or that the value of ΔT would increase. Only stronger responses mentioned the decrease in the calculated amount of ammonium bromide and linked this to the decrease in percentage by mass of the salt.

(d) Maximum uncertainties and maximum percentage errors have been in many question papers previously and this is an area which candidates find demanding. As the thermometer is read twice to obtain a value for ΔT the maximum uncertainty had to be doubled. Some candidates used one or both of their thermometer readings as their denominators instead of ΔT. Only a few omitted multiplying by 100.

Question 3

Candidates should be encouraged to read through the guidance given at the start of the qualitative analysis section. Use of the Qualitative analysis notes would have helped some with describing their observations.

(a) (i) When heating a solid ‘unknown’ it is important to heat gently initially so any water driven off has a chance to condense on a cooler part of the hard-glass test-tube. It seems that some candidates did not heat **FA 5** sufficiently strongly. Very few noted the production of the purple gas and some missed the change in colour of **FA 5**. The use of ‘ppt’ for ‘solid’ by some candidates was incorrect: exact terminology is expected at this level.

Almost all candidates noted effervescence/fizzing/bubbling on adding **FA 5** to acid but fewer tested the gas. Many of those who used limewater did not state a white precipitate was formed: ‘milky’ or ‘cloudy white’ are not acceptable alternatives at this level. Many candidates correctly noted the solution formed was yellow.

(ii) This part was demanding for candidates. In **Test 1**, a wide range of colours was accepted as centres were likely to use different concentrations of sodium chlorate(I). The colour was due to the formation of iodine which was expected to be reduced back to iodide on adding the sodium thiosulfate. In **Tests 2** and **3**, candidates needed to remember that the solution they were testing was acidic so more alkali than usual would be needed to obtain complete observations. Some candidates reported a blue precipitate in **Test 4** which suggests they did not carry out the test. The colour of the precipitate of copper(I) iodide is difficult to see owing to the formation of aqueous iodine. This meant that a range of colours of the precipitate were accepted. However, the addition of sodium thiosulfate in the second part should have removed the colour of the iodine leaving a white precipitate and a (pale) blue solution of excess copper(II) sulfate. Almost all candidates recorded a precipitate in **Test 5** but some described it as off-white or cream instead of (pale) yellow. Most noted correctly that the precipitate was insoluble in aqueous ammonia.

(iii) Many candidates did not link their answers to one of the tests in **(a)(ii)**. However, a substantial minority gained credit for suggesting a white precipitate would be formed in **Test 5** or with (aqueous) silver nitrate.

(iv) Most candidates gave correct formulae but not necessarily of the correct ions.

(b) (i) Candidates should be encouraged to think about possible outcomes of their tests. The use of solid sodium carbonate is to find out whether **FA 9** is an acid or an alcohol. Comments regarding the solubility of the solid in **FA 7** and **FA 8** were not creditworthy. Candidates should have been looking for effervescence. There was no need to test with limewater here as the only possible gas was carbon dioxide. Those claiming the gas popped with a lighted splint were not awarded credit.

(ii) Most candidates were able to conclude that the functional group in **FA 9** was carboxyl. However, some suggested **FA 9** was either a carboxylic acid or an alcohol which contradicted the results of their test in **(b)(i)**. Fewer candidates were successful in stating **FA 7** and **FA 8** were carbonyl compounds. Some stated they contained C=O without also including CHO. Some candidates attempted to identify **FA 7** as a ketone and **FA 8** as an aldehyde (or vice versa) which was an incomplete answer given the information available from the tests.

(iii) Candidates who performed well generally used the expected potassium manganate(VII)/$KMnO_4$: the name or formula of the reagent had to be fully correct to gain credit.

A common error in the observations was to omit which of **FA 7** or **FA 8** was being tested. Candidates were expected to record the identities of **FA 7** and **FA 8** rather than simply whether each was an aldehyde or a ketone. Some incorrectly identified one of them as an alcohol which contradicted the result with 2,4-DNPH given in **(b)(i)**.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- ensure they follow the instructions in the method
- show the precision of the apparatus used in their recorded data
- use the full name or correct formula to describe any reagent selected for use in a test
- 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
- ensure their answers, particularly numbers, are clearly legible. Errors or rough work should be crossed out rather than being over-written with the new answer.

General comments

This paper generated a wide range of marks.

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.

Supervisor 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 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.

Larger centres with several different supervisor results scripts relating to different laboratories and sessions are requested to ensure that all candidate and supervisor scripts are correctly labelled with these details on the front cover so that each candidate's results are assessed against the correct supervisor's results.

Centres are reminded that the descriptions of solutions on the question paper are not always the same as the solutions provided to the candidates as instructed in the Confidential Instructions. Candidates must assume that the information given in the question paper is correct.

Comments on specific questions

Question 1

Most candidates performed well in **(a)** and **(b)**. The experiment was a back titration. Candidates needed to carefully read the process to understand the steps involved. Many candidates found this challenging and performed less well for **(c)** and **(d)**.

(a) Credit was available for the collection, display and accuracy of titration data. Many candidates performed well on this titration experiment as shown by use of appropriate headings, the correct precision of readings and concordant titres. Concordant titrations are obtained when two titres are within 0.10 cm^3. Once concordance has been achieved, there is no reason to continue with further titrations. Most candidates gained some credit for accuracy. Some candidates did not record the burette readings for a rough titration, incorrectly recording initial burette readings of 50(.00) cm^3 or burette readings greater than 50.

(b) Candidates performed well here. Candidates are reminded that working should be clearly shown. The titres used should have a maximum spread of no more than 0.20 cm^3 and the mean should be shown to 2 decimal places.

(c) (i) Given the precision of the apparatus and the listed concentrations of the reagents, all numerical answers in **(c)** were expected to be given to 3 or 4 significant figures. Some candidates wrote this on their paper but then did not follow their own advice. Common errors were providing an answer to one significant figure for **(c)(iii)** or not providing an answer for **(c)(iv)**.

(ii) This was challenging for candidates to achieve. It required candidates to convert the concentration of **FB 3** from $g\,dm^{-3}$ to $mol\,dm^{-3}$ and then to scale the number of moles for the 25.0 cm^3 used. Some candidates incorrectly used the mean titre from **(b)** in place of 25.0, rounding values during the calculation or rounding the final answer incorrectly. The Periodic Table on the examination paper gives all relative atomic masses to 1 decimal place. Some candidates also incorrectly used 39 for the relative atomic mass of potassium rather than 39.1.

(iii) Candidates are expected to be familiar with writing ionic equations but many candidates were not able to do this. A balanced ionic equation shows the *reacting* ions in a chemical reaction. Spectator ions, in this case potassium and chloride, should be omitted.

It was at this stage that the candidate's titre was required. The ionic equation establishes that one mol of hydroxide ions in **FB 3** reacts with one mol of hydrogen ions in **FB 2**. The concentration of HCl in **FB 2** can be calculated using the titre and **(c)(ii)**. A common error was to calculate the initial concentration of HCl in **FB 2** (0.500 $mol\,dm^{-3}$).

(iv) This calculation was challenging. Candidates were informed they should use the information about **FB 2**, given at the start of **Question 1**, and their answer to **(c)(iii)**. The first step, subtracting **(iii)** from the initial concentration of HCl in **FB 2** (0.500 $mol\,dm^{-3}$), was commonly missing. Although errors seen in **(ii)** were carried forward, some values produced at **(iii)** then made it difficult to obtain an answer here.

Candidates who did not carry out the first step of the calculation were often able to gain credit as many appreciated that a value of moles, either the answer to the first calculation step or to **(iii)**, should be divided by four to take account of the reaction stoichiometry and they were able to calculate the M_r using the mass of **FB 1** of 22.5 g.

(d) Information given at the start of **Question 1**, that a small excess of hydrochloric acid was used, was required. Only those candidates who understood the process of the reaction and had carefully read the information at the start of the question were able to answer this correctly.

Question 2

The thermal decomposition method was clearly familiar to most candidates and calculations were often correctly carried out. Part **(c)** was more challenging. Candidates would benefit from greater discussion of errors arising from different practical procedures.

(a) This question gave some assistance to the candidates by providing printed headings, however, candidates were expected to give units and some did not. Some candidates did not follow the instructions to record the correct calculated values in the other results section. It was common to see mass lost calculated in place of mass of residue. The lower of the two values for mass after heating should be used to calculate the mass of residue.

The vast majority of candidates gained some credit for accuracy with many gaining full credit. However, the range of values across centres for masses after heating was large. Some centres had obviously used spirit burners and declared this on the Supervisor's Report form, but in other centres there was a very broad spread of results suggesting that some candidates may have had different burners or some had heated with the lid on. It is essential that all candidates use the same heating equipment and if this is not possible, it must be declared on the Supervisor's report.

(b) (i) The equation given was frequently correct with the most common errors being either missing state symbols or the incorrect state symbol for water vapour.

(ii) This calculation was frequently correct but credit was sometimes not awarded because the answer was given to too many significant figures.

(iii) The low mass loss caused either by use of a spirit burner or incorrect heating produced some large values for M_r, which gained full credit.

(iv) This question was answered successfully by most candidates attempting it. Common errors were to not divide by 2 or not showing any working.

(c) (i) Candidates were required to explain that the solid in the crucible after heating is **M**O rather than **FB 1**. Very few candidates answered this correctly. Candidates should be encouraged to make use of all the information provided.

(ii) Although candidates were generally aware of the need to heat to constant mass many did not refer to their own results as required by the question.

(iii) Candidates found this question very challenging. When suggesting why an experiment is *more* accurate, responses should be comparative, such as 'the colour change at the end point of the titration is harder to judge than the mass loss'. Human errors and parallax errors were common incorrect explanations.

Question 3

Candidates should be encouraged to read through the guidance given at the start of the qualitative analysis section. Use of the Qualitative analysis notes would have helped some with describing their observations.

(a) (i) Candidates should be encouraged to note the starting appearance of the solid. It is good practice to start a thermal decomposition by first heating gently before heating strongly, however this was rarely described by candidates. In this case, gentle heating would result in condensation being clearly visible. Candidates often successfully described testing the gas produced using litmus paper and noted that the solid sublimed or disappeared. Several candidates referred to the solid as a precipitate which is incorrect.

(ii) The production of an alkaline gas in **(i)** informed the candidates that the cation was likely to be ammonium. The further test of heating with NaOH(aq) and testing the gas produced with litmus is given in the Qualitative analysis notes. Those who did not heat the mixture or if it was not communicated clearly that the gas, not the solution, was tested with litmus did not gain credit.

(iii) The addition of acid to the carbonate results in a vigorous reaction and this should have been recorded. Effervescence was often recorded, but the gas produced was not always tested. It must be clear that it is the gas that is tested. At this level, the correct observation for a positive test for carbon dioxide is that a white precipitate is formed with limewater (not 'cloudy' or 'milky').

(iv) Ammonium carbonate was identified well although a few candidates did not gain credit as they named the compound or wrote an incorrect formula.

(b) Candidates are asked to record details of test(s) used. Reagents must be identified by the correct formula or name, e.g. OH^- is not acceptable in place of NaOH. If a second reagent is used in a test, it must be clear whether this is being added to the same test-tube or whether it is a separate test.

(i) Candidates were able to select the correct reagent for this test and in most cases accurately describe the result in accordance with the description for chromium(III) ions in the Qualitative analysis notes.

(ii) The question states that a positive test is required so in this case, reporting that there was no precipitate with silver nitrate was not awarded credit. The required reagents were NaOH(aq) and A*l* and the mixture needs to be heated, which was not stated by some candidates. As one reactant is an alkali, it must be made clear that it is the <u>gas</u> (or ammonia) produced that is tested with litmus. A test with acidified potassium manganate(VII) was not required as it would not give a positive test for nitrate.

(iii) This question was very challenging. Precipitates are formed by the mixing of two solutions or by bubbling a gas through a solution. Most candidates incorrectly suggested adding solid **FB 8** to either sodium hydroxide or ammonia solution. The correct first step in this test is to make a solution from the reaction of **FB 8** with a named acid, however, few candidates suggested this.

(iv) To carry out the triiodomethane (iodoform) test, both aqueous iodine and NaOH(aq) must be used. Most candidates suggested using the available, but as yet unused, aqueous iodine but many did not add NaOH slowly after excess iodine and hence the test did not work. ‘Alkaline iodine’ was not an acceptable reagent.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

Candidates should:

- 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 the volume of solution when calculating energy change using the expression $q = mc\Delta T$, as the density of dilute solutions is very close to $1.0\,g\,cm^{-3}$
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance.

Supervisor results for the quantitative and qualitative tasks are used in awarding accuracy marks in **Questions 1** and **2** and as a check on the ‘unknowns’ and reagents in **Question 3**. It is advisable that the best practical chemist in the centre carries out the experiments.

General comments

Candidates should be reminded that the instructions state that although an HB pencil may be used for diagrams and graphs, the remainder of the paper should be completed in dark blue or black pen. A number of candidates completed the whole paper in pencil.

Any issues with supply or preparation of chemicals 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.

Supervisors must provide their results on a spare copy of the examination paper clearly labelled as ‘Supervisor’s results’. This information is required for examiners to award marks for the accuracy of the candidates’ work.

The confidential instructions make it clear that an additional supply of chemicals should be provided to candidates without penalty. It is not acceptable to report that a candidate was unable to complete a question as they had no chemicals available or had run out of chemical.

As stated in the apparatus list in the confidential instructions, any thermometer must have units of Celsius and not Fahrenheit.

Candidates in some centres found this component very challenging and were unable to attempt one or more of the three questions.

Comments on specific questions

Question 1

(a) Candidates were generally able to prepare a table for their results with appropriate headings, however the unit for rate, s^{-1}, was often missing. Data should be recorded to an appropriate precision for the apparatus used. Water was measured with a measuring cylinder of precision 0.5 cm^3. It was common to find this recorded either to 0.05 cm^3 (suitable for the **FA 1** measured by burette, but too precise for the measuring cylinder) or to zero decimal places. Time should be recorded to the nearest second as instructed. This should be an integer – time given to one or more decimal place is not to the nearest second. Rate was generally calculated well, although some rounding errors were observed. The experiment was generally carried out well with the ratio of the reaction time for Experiment 2 : Experiment 1 correctly calculated to be approximately 2.00.

(b) (i) The concentration of potassium peroxodisulfate is proportional to the volume of **FA 1** as the total volume of the solution remains the same in Experiments 1 and 2. Answers giving mathematical explanations were acceptable. However, this question was challenging for many candidates with responses stating only that **FA 1** was potassium peroxodisulfate.

(ii) Following **(b)(i)**, candidates should have recognised that the total volume of **FA 1** and distilled water should be 20.0 cm^3 and that **FA 2** and **FA 3** should have the same volume as in **(a)** for a further experiment to be valid. Some candidates were able to suggest a suitable volume for **FA 1** that was at least 2.5 cm^3 away from the values already used, but could not state the correct volume of water.

(c) This question required an explanation of the difference in the candidate's reaction time if the concentration of the sodium thiosulfate solution was increased. Answers given in terms of rate did not gain credit. Candidates referring to time being 'slower' or 'faster' were not credited. Candidates recognised that a greater concentration of solution generally decreases reaction time, however in this reaction the thiosulfate is reacting with the iodine formed. Therefore, the greater the concentration, the greater the amount of thiosulfate present and more iodine will need to be formed before the colour change to blue-black with the starch indicator. Therefore, reaction time increases. Candidates who indicated that this change may result in no visible end point appearing were given credit.

(d) A large excess of a reactant is used in a rate experiment to ensure that the concentration of the reactant remains constant, so it does not affect the rate. Few candidates provided this response.

Question 2

(a) This question was challenging for candidates. Credit was available for the recording of data. The Cambridge Handbook and the confidential instructions provide information that thermometers should be calibrated at 1 °C so be read to a precision of 0.5 °C. Readings were often presented to 1 decimal place rather than to 0.5 °C. Results were often presented in an unclear way and missing any readings regarding the weighing of **FA 5**. However, accuracy of measurement of the temperature change was good relative to the supervisors so a large majority of candidates gained credit for accuracy.

(b) Construction of a graph was generally done well. Points should be plotted neatly with a small cross and scales should be based on 1, 2 or 5. It was noticeable that scales using divisions of 3, 7 or 9 often resulted in the incorrect plotting of points. Centres should ensure that candidates have experience of drawing lines of best fit as many were incorrectly constructed. Points should be evenly balanced around the line and the line be incapable of rotation. Anomalous points should be indicated; this instruction was given, but often not followed. Equally, the instruction to extrapolate the two lines to 2.5 min was also sometimes not followed. At 2.5 minutes the temperature should be less than or equal to the lowest temperature recorded.

(c) (i) Given the issues reported in **(a)** and **(b)**, candidates were often not able to provide a temperature change or did not follow the instruction to use their graph to do so.

(ii) Use of $q = mc\Delta T$ was poor. Common errors were the use of the mass of **FA 5** instead of the solution or adding the mass of **FA 5** to the mass of the solution. Use of data from **(a)** was given credit, but this did indicate that candidates did not understand that they had drawn a graph to compensate for heat gain in this endothermic reaction. It was not acceptable to use 4.2 as the value for c; it was given as 4.18 on the examination paper.

(iii) Calculation of the number of moles of ammonium chloride was generally done well.

(iv) It was necessary to include the sign (positive for this endothermic reaction) and to quote the answer in kJ mol^{-1} by dividing the answer by 1000. Common errors by candidates included providing an answer of **(c)(ii)**/1000 or repeating **(c)(ii)**. Candidates should note that the units for enthalpy change, ΔH, were provided in the question stem and on the answer line. This demonstrates the importance of making use of all the available information provided in the question paper.

(d) Candidates were asked to show their working for this question. Some responses were incorrect as the error in single readings were presented rather than in the temperature change requested. Some responses incorrectly summed the errors in all the readings taken rather than the 2 × 0.5 required for the two readings needed to calculate the requested temperature change.

Question 3

(a) (i) The stem of this question stated that a gas is produced when heating **FA 6**. Few candidates tested for a gas and very few identified oxygen.

(ii) The colour changes were found to be easy to see and were recorded appropriately. However, candidates often showed confusion with the terms residue and filtrate. Candidates should use technical terms appropriately.

(b) (i) Effervescence, fizzing or bubbles are evidence that a gas is being formed. In the question introduction, the candidates are told to identify gases by means of a suitable test. Few candidates tested their gas using limewater to identify carbon dioxide and hence found that **FA 8** contained a carbonate ion. Centres should note that as per the Qualitative analysis notes, the correct description for a positive carbon dioxide test with limewater is that a white precipitate is formed in the limewater. Descriptions such as ‘milky’ and ‘cloudy’ limewater are not credited.

When no change occurs, the result of this test should be recorded as ‘no change’ as stated in the instructions.

Descriptions of the results of the qualitative analysis tests should be succinct, use appropriate terms and should follow the guidance given in the question paper. For example, if a gas is formed then the gas should be identified. If there has been a colour change, then the Qualitative analysis notes should be used to describe the colours if appropriate. If a precipitate is formed, it should be described as a precipitate (not hazy, cloudy) and solubility of the precipitate should be tested by adding an excess of the reagent. The result should be clearly noted as either the precipitate being soluble or insoluble in excess.

(ii) Ions were identified rarely. Many candidates interpreted the results of **Test 3** with **FA 8** (a white precipitate with barium chloride that dissolved in acid) as the presence of a sulfite ion. However, in both **Test 3** and **Test 1** effervescence should have been observed with acid. If the candidates tested the gas, they would have had evidence that the anion was carbonate. Copper(II) and sulfate ions were identified as part of **FA 9** by more candidates, but few identified that the second cation in **FA 9** was H^+. This could be identified by effervescence with **FA 8**.

(iii) Only the strongest candidates were able to provide a correct ionic equation. Many candidates did not attempt this question.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- The question paper asked for several definitions. Candidates who had learnt these carefully, rather than attempting a loose description, gained more credit.
- Some candidates had poor handwriting which meant that some responses were illegible. If words are written in such a way that they could be read in more than one way – for example, as either exothermic or endothermic, then credit is not awarded. This also happens with numbers, 1 and 2 can be written in a similar way, so can 4 and 9. Credit is not awarded in such cases.
- If a candidate wishes to change an answer, they must cross out their original answer completely. If there is insufficient space to write their replacement answer, there is plenty of blank space on the question paper. A comment to identify where an answer is written should be included, such as 'continued on page 5'.
- Answers to calculations should be given to a minimum of two significant figures but three significant figures are preferred or sometimes required. 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 three significant figures.
- In an extended calculation worth several marks, such as **Question 1(b)**, the explanation of the working is important.
- The questions on organic chemistry required formulae to be drawn. Candidates should use displayed, structural, or skeletal formula. Examples were seen where these types of formulae were mixed, and some skeletal formulae where either the carbon atoms, or the hydrogen atoms, but not both, were drawn in. Candidates should be strongly discouraged from taking this approach, which runs the risk of losing credit.
- Care should be taken when drawing curly arrows and labelling partial charges to show organic reaction mechanisms. A curly arrow should start clearly on a bond or on a lone pair and the arrowhead should point clearly in the direction of the destination of the electron pair. In electrophilic substitution mechanisms, the curly arrow in the first step should start on the circle within the hexagon and end at the positively charged electrophile. The curly arrow in the second step should start in the middle of the C–H bond that is about to break. It should end at the broken circle within the hexagon.

General comments

It is emphasised that both care and the correct following of convention is needed when writing the formulae of substances. In **Question 8(b)(ii)** care was needed to show the salts of the carboxylic acids as either $-COO^-Na^+$ or $-COONa$, but a mixture of these two approaches, i.e., $-COO^-Na$ and $-COONa^+$, lost credit.

The majority of candidates were able to work through to the end of the paper. Some candidates may have given up. This should be discouraged, as many candidates found parts of later questions, such as **Question 8** and **Question 9**, very accessible.

Many candidates had good ability to show the skills needed to answer an examination paper of this type. Better performing candidates showed good skills in:
- 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
- drawing the stages of a reaction mechanism.

Comments on specific questions

Question 1

(a) (i) This was answered well by many candidates. Some focused on charge density of the cation and the consequent distortion of the anion; this approach often gained partial credit.

(ii) Credit was very rarely awarded for this question. Many candidates made statements about 'more OH^-'. However, a high pH is due to a higher **concentration** of OH^-.

(b) This question discriminated well. Many candidates could work through as far as $[OH^-] = 0.0158\,mol\,dm^{-3}$ but got stuck at this point. Other candidates worked past this to a final answer of 0.679 g, gaining three marks. It is important to emphasise the large number of candidates who may have lost marks by not explaining their working. Examiners cannot award credit by picking unexplained numbers such as 0.0158 out of a candidate's response. Such numbers must be clearly identified, for example as '$[OH^-] = 0.0158\ mol\,dm^{-3}$'.

(c) (i) Credit was often awarded for this question. $K_{sp} = [Fe^{2+}][2OH^-]^2$ was a common incorrect answer.

(ii) This was answered well by many candidates.

Question 2

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

(ii) This was answered well by many candidates. The distinction between 'partly filled d-orbitals' in **Question 2(a)(i)** and 'empty d-orbitals' in **Question 2(a)(ii)** was important.

(b) (i) Most candidates gave a correct definition. Some candidates wrongly gave a definition of 'non-degenerate'. No credit was given for 'orbitals of similar energy'.

(ii) Most candidates could sketch the shape. The commonest error was to draw the lobes along the x and y axes, rather than between them.

(c) Many candidates found these equations particularly difficult. It should be noted that when NaOH(aq) is a named reactant it is extremely unlikely that HNO_3 will be a product of the reaction.

(d) Many candidates gained at least one mark. The deduction that the H–N–Ag bond angle is equal to or close to 109.5° was found difficult.

(e) This was found to be very difficult by many candidates. Many half-equations were seen that did not involve Ag^+ gaining electrons at the positive electrode, or Zn losing electrons at the negative electrode; such answers gained no credit.

(f) One mark was often awarded for a diagram in which N—N acts a bidentate ligand bonded to two different Ru^{3+} ions. Incorporating this knowledge into two repeat units of the polymer was more rarely awarded.

Question 3

(a) Very many unbalanced equations were seen. Some candidates ignored the information given in the question and submitted an equation that did not include a carbonate compound.

(b) It was very important for candidates to make it clear which substance, or ion, they were describing when answering this question. Statements such as 'ionic radius increases' or 'it has a greater ionic radius' could refer to any one of Ca^{2+}, Ba^{2+} or $C_2O_4^{2-}$. A statement such as 'ionic radius increases down Group 2 from Ca^{2+} to Ba^{2+}' or 'Ca^{2+} has a smaller ionic radius' is clear, unambiguous and correct. A significant number of candidates discussed the strength of attractive forces between the anion and the cation, rather than the polarisation of the anion by the cation.

(c) This was answered well by many candidates, who showed that they had prepared well for this type of question.

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

(e) Good quality three-dimensional diagrams that gained full credit were seen in many responses.

(f) It was common to see one correct equation, $HC_2O_4^- + H^+ \rightarrow H_2C_2O_4$. It was rarer to see $HC_2O_4^- + OH^- \rightarrow C_2O_4^{2-} + H_2O$. Many candidates wrote $H_2C_2O_4 + OH^- \rightarrow HC_2O_4^- + H_2O$. This is incorrect; the concentration of $H_2C_2O_4$ in the solution is too low to have an effective buffering action.

(g) Full credit was often awarded, although both the equation and the $E^{\ominus}_{cell}$ required care.

Question 4

(a) Full credit was often awarded. Errors seen included:

- describing the SHE as a cell, rather than as an electrode or a half-cell
- omitting the description of standard conditions.

(b) (i) This was answered very well. Some candidates omitted the liquid levels in the beakers or drew in liquid levels that would not touch the electrodes or salt bridge.

(ii) Although some excellent answers were seen, many answers referred to ‘the equilibrium’ or ‘the equation’ shifting to the left without specifying which equilibrium or equation they meant.

(c) Most candidates gave a correct definition. Weaker definitions ended with ‘…to form one mole of aqueous ions.’ When one mole of ionic solid is dissolved in water the **minimum** is that two moles of aqueous ions are formed.

(d) (i) This question discriminated well.

(ii) Some candidates omitted the minus sign.

(e) Although some excellent answers were seen, many candidates ignored, or were unaware of, the instruction in the syllabus to explain the effect of **ionic charge** and **ionic radius** on the numerical magnitude of lattice energy. Answers that did not focus on these two factors inevitably lost credit. Some answers focused on ionic radius only, ignoring the greater charge on Mg^{2+}.

Question 5

(a) (i) This was often correct. However, tangents were sometimes seen at other places on the curve, where the value calculated cannot be the **initial** rate of reaction.

(ii) This question was found to be difficult by many candidates. Many answers were seen that discussed limiting reagents; these gained no credit. The key to the explanation is that using a large excess of iodide ions keeps the concentration of iodide ions effectively constant, so that the rate of the reaction depends only on the concentration of persulfate ions.

(b) Many candidates were well prepared for questions based around this material. Errors included unbalanced equations and not including Fe^{2+} in equation 1.

(c) The effect was often correctly described.

(d) The half-life was usually correctly calculated.

(e) This discriminated well. Many candidates lost marks having written equations that were unbalanced for charge.

Question 6

(a) (i) This question discriminated well. A successful answer had four key components: ratio, concentrations, solute, solvents – that had to be found within a meaningful sentence.

(ii) Candidates found this very difficult. Firstly, it was necessary to calculate that there is 0.74 g of **X** in the 40 cm^3 of aqueous solution. Then the equation $10.5 = (y \div 25) / ((0.74 - y) \div 40)$ had to be written, where y is the mass in grams extracted into CS_2. Having done this, the equation needed to be evaluated.

(b) Full credit was often awarded. Some answers suggested that one or more of the structures contained more than six carbon atoms.

(c) This material is not well known by many candidates. 'C–C bonds are p bonds only' was a commonly seen part of many answers. Another issue was where candidates described s and p bonds without stating whether these bond types are found in C–C bonds or C–H bonds.

(d) This question was found to be difficult by many candidates. Very few answers were seen that recognised the significance of inter-bond repulsion to the stability of Dewar benzene and Ladenburg benzene.

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

(f) (i) The equation was often correct. However, care was needed to ensure correct copying of the formulae given in the question.

(ii) Some common errors included:

- showing the positive charge on the intermediate near to the sp^3 hybridised carbon atom, rather than in the centre of the hexagon
- drawing the start of the second curly arrow on the hydrogen atom, rather than on the C–H bond.

(iii) Very few candidates appreciated the ability of the terminal $–CH_2Br$ group to react with a second molecule of phenylethanone, or to react with the benzene ring of the initial product.

Question 7

(a) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(b) (i) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(ii) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(c) (i) This question discriminated well.

(ii) This question discriminated well. Many candidates thought that ester **C** would have a triplet peak in its proton (^1H) NMR spectrum. This is incorrect.

(d) This was a very demanding question requiring careful examination of the information given, systematic thinking and a thorough knowledge of A-level organic chemistry. The following points relate to errors seen on many scripts.

- Organic structures, using either displayed or skeletal formulae, should be drawn with care.
- Knowledge and the application of valency is of great assistance to candidates when answering such a question. Many three-valent or five-valent carbon atoms were seen.
- The question gives molecular formulae for compounds **F**, **J** and **K**. Those candidates who submitted answers as displayed formulae probably found it easier to check they had included the correct number of hydrogen atoms.
- When a positive iodoform test is performed, the yellow precipitate is CHI_3, not CIH_3.
- $LiAlH_4$ does not reduce a C=C double bond.
- When $SOCl_2$ reacts with a –COOH group the product is a –COCl group, not a –COOCl group.
- When a –COCl group reacts with propan-2-ol the ester formed has a $–COOCH(CH_3)_2$ group, not a $–COOCH_2CH_2CH_3$ group.

Question 8

(a) (i) Most candidates correctly stated the number of chiral carbon atoms.

(ii) The functional groups were usually identified. Commonly seen wrong answers included ketone and ‘carboxylic’ on its own, rather than ‘carboxylic acid’.

(b) (i) This question discriminated well.

(ii) This question was found to be difficult by many candidates. It required detailed knowledge of the chemistry involved. Care had to be taken when drawing structures. It should be noted that methanol does not react with hot NaOH(aq) to form $CH_3O^-Na^+$.

Question 9

(a) (i) The equation was usually correct. Wrong answers included unbalanced equations and equations with H^+ or H_2O as one product.

(ii) This question discriminated well. Incorrect answers included:

- structures with –NO or $–NO_3$ side groups
- structures without –OH groups
- two identical structures, such as two 3-nitrophenol molecules drawn as mirror images.

(b) This was found to be difficult, although some excellent answers were seen. Much care was required to show the structures correctly.

(c) (i) This was found to be difficult. It should be noted that to produce the three new bonds needed to form cyclohexene, the three curly arrows had to be either all clockwise, or all anticlockwise.

(ii) This was found to be difficult.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

- Candidates must ensure their presentation is clear.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through and a new answer should be written in the available space.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows are a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

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

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

Comments on specific questions

Question 1

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

(b) This was generally well answered. Common errors were:
- omitting 1 mole with ionic compound formed
- starting from 1 mole of gaseous ions.

(c) Some candidates did not clearly separate the ideas of ionic radii and ionic charge within charge density of the ions in their explanation. Some confusion was evident in answers such as 'ionic radius and charge density of the ions' since ionic radius is a contributory factor to charge density.

(d) (i) This was generally well answered and many candidates correctly identified the species. The completion of the energy cycle was found to be more challenging. Common errors included omission of electrons and state symbols.

(ii) Candidates performed well on this question. Common errors included –1969.5 (265 ÷ 2 used, S – S bond enthalpy, instead of 279) and –1608 (no 2 × with K).

Question 2

(a) (i) This proved difficult for many candidates. Many gave LiO as the formula for lithium oxide or incorrectly balanced the equation.

(ii) Many candidates gave a correct statement regarding increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion was less frequently seen.

(b) Many correct answers were seen for this question. Some common errors were:
- 5.35×10^{-2} (omitting to calculate the moles of unreacted MnO_4^-)
- 1.75×10^{-2} (incorrect calculation of the moles of unreacted MnO_4^-)
- 1.52×10^{-2} (omitting × 4 in the calculation of the concentration of $NaNO_2$ in **X**).

(c) (i) This was generally well answered and many candidates gave a suitable equation. Common errors were incorrect balancing for the equation or not simplifying the equation, for example
$MnO_4^{2-} + 2MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$.

(ii) Candidates found this question challenging. Explanations frequently omitted H^+ decreases or did not relate to the equilibrium. A common error was stating that H^+ increases as pH increases.

Question 3

(a) 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 their calculated values for ΔH and ΔS. Common errors included use of T = 25 (instead of 298), omitting dividing ΔS by 1000 or a sign error in the calculation of ΔH and ΔS.

(b) This answer was usually correct. Common errors included –716 and 0.716.

Question 4

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

(ii) Many accurately drawn correct answers were seen. However, sometimes it was difficult to distinguish between the ‘doughnut’ shaped electron cloud and a s-orbital in between a lobe along the *z*-axis.

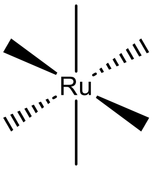
(b) Candidates performed well on this question. Solution **A** was more well-known than solution **B**. Common errors included $(Cu(OH)_2(H_2O)_4))^{2+}$, $(Cu(NH_3)_6))^{2+}$ and $(CuCl_4)^-$.

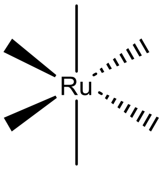
(c) Candidates found this question challenging. Candidates were expected to state:
- (Ag^+) d-subshell is full or d-orbitals̲ are full
- no d electrons are promoted/excited.

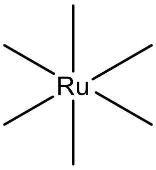
Common errors included stating Ag^+ has a full d-orbital and there was no d-d splitting.

(d) This was generally answered well. Some candidates omitted ‘metal’ with metal atom/ion.

(e) (i) Many accurately drawn correct answers were seen, using correct conventions for the three-dimensional bonds of wedged and dashed bonds. The most common errors were:
- diagrams without any 3-D bonds
- diagrams in which 3-D bonds were drawn but where the complex could not be octahedral, for example:







(ii) This answer was usually correct.

(iii) This proved challenging for candidates. Many did not describe dipoles (partial charges) cancelling but stated that bonds or polarities would cancel.

Question 5

(a) (i) This was usually answered well, with a good understanding of the initial rates method. The order with respect to NO was normally correct. The order with respect to Cl_2 often omitted any link to NO. Most candidates were able to construct a rate equation from their orders.

(ii) The calculation of the rate constant *k* was usually correct. Many candidates incorrectly gave the units as $mol^{-2}\,dm^{6}\,s^{-1}$ instead of $mol^{-2}\,dm^{6}\,min^{-1}$.

(b) Full credit was rarely awarded. Candidates were told NO_2Cl undergoes homolytic fission to release chlorine radicals that catalyse the conversion of ozone, O_3, into oxygen and asked to complete the mechanism as shown. The correct answer is shown.

initiation $NO_2Cl \rightarrow Cl\bullet + NO_2\bullet$
step 1 $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$
step 2 $ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$

Candidates frequently omitted the dot to indicate a radical species and many did not write an equation showing chlorine radicals acting as a catalyst or ozone being converted into oxygen.

(c) Many correct answers were seen for this question. A common error was not using the order of reactions for the O_3 and NO_2 given to write the first equation. Some weaker responses gave unbalanced equations containing charged species such as NO_3^-.

Question 6

(a) (i) Candidates found this question challenging. Many candidates stated the definition of an acid and a base instead of giving a precise definition of a conjugate acid-base pair.

(ii) This was generally well answered. Some gave the equation for the weaker acid, CH_3CH_2COOH.

(b) (i) This answer was usually correct.

(ii) Many good answers were seen for this question. Most candidates were able to calculate the $[H^+]$ and the K_a. A common error was using the Henderson-Hasselbalch equation to calculate the [HA].

(c) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating the pH would remain unchanged or omitted ‘small’ amounts of acid and base should be added.

(ii) Candidates generally found this question challenging. Common errors included:

- using the original (CH_3COONa) of 0.125 $mol\,dm^{-3}$ instead of the calculated moles of CH_3COONa of 0.05
- omitting converting the moles of CH_3COOH (5.60×10^{-3}) to (CH_3COOH).

(d) (i) Candidates performed well on this question. Common errors were giving an unbalanced equation or inclusion of O_2 or O on the left-hand side.

(ii) This was generally well answered. A common error was 2238 cm^3 (omission of × 4).

Question 7

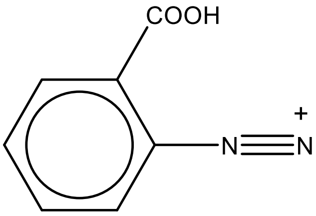
(a) (i) Candidates often gave the correct answer here. Common errors included omitting the '2' and 2-nitrobenzonoic acid.

(ii) Most candidates answered this question well. Some omitted 'heat' from their answer.

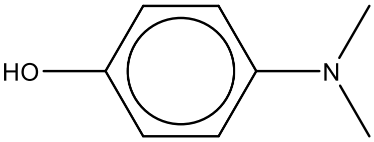
(iii) The electron withdrawing and directing nature of −COOH was generally well known. Some candidates stated that the –COOH is a deactivating group or incorrectly stated that it activates positions 3 and 5.

(b) (i) The structure of **Q** (2-aminobenzoic acid) was normally correct. The correct structures of **R** and **S** were less common. The most common errors seen for **R** and **S** were:

incorrect **R**



incorrect **S**



(ii) This was answered well. The most common errors were:

- for step 1: omission of 'concentrated' with HCl
- for step 2: use of $NaNO_3/HNO_3$ instead of $NaNO_2/HNO_2$.

Question 8

(a) Many candidates gave a correct order: benzylamine – ammonia – phenylamine. Some good explanations were seen. Most candidates knew that alkyl groups have a positive inductive effect and the electrons from the NH_2 group were delocalised into the ring. Points of note are:

- basicity of these compounds is due to the ability of the lone pair of electrons on the nitrogen atom to accept/form a coordinate bond to a proton
- 'attract a proton' is not equivalent to 'accept a proton'
- candidates had to identify that the 'lone pair from the nitrogen atom' rather than just 'electrons from the NH_2 group' were being delocalised into the ring.

(b) (i) Most candidates correctly identified that 2,4,6-tribromophenylamine would be formed. Some omitted that a white precipitate would be formed.

(ii) Candidates performed well on this question. Most candidates recognised that the lone pair on the N of NH_2 is delocalised into the benzene ring, which leads to the electrophile being attracted and polarised more. The explanation to the effect on the electron density of N was normally absent or in terms of increased charge density.

(c) This was not well known. The lack of basicity of an amide is due to the lone pair of electrons on the nitrogen atom being delocalised into the C=O group.

(d) Many candidates found this challenging. Some good answers were seen. Common errors included:

- omitting the lone pair on the N on NH_3
- omitting the dipole for the C=O bond
- an incorrect intermediate structure
- the first curly arrow in the intermediate going from the O^- to the C atom instead of the C−O bond
- the second curly arrow in the intermediate starting at the C instead of the C−C*l* bond to the C*l*.

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

(ii) This question was usually answered correctly.

(f) 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.

Question 9

(a) This question was generally well answered. Most candidates stated that chlorine is electron withdrawing, however, they did not state that they would weaken the O–H bond or stabilise its conjugate base.

(b) (i) Candidates found this question challenging. Some candidates omitted the stoichiometry or incorrectly gave H_2O as a product.

(ii) This question was found to be challenging. Candidates were more successful in determining the structure of the second product. Most candidates identified the first product as ethanedioic acid instead of CO_2.

(iii) Many good answers were seen for this question and most were able to draw one repeat unit. Common errors included omitting or having an oxygen atom in their section of the polymer or omitting the continuation bonds.

(c) (i) Most candidates gave the correct answer for this question. The most common error was CH_3I.

(ii) Most candidates were able to identify 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 ten in total.

(iii) Credit for this question was rarely awarded.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- The question paper asked for several definitions. Candidates who had learnt these carefully, rather than attempting a loose description, gained more credit.
- Some candidates had poor handwriting which meant that some responses were illegible. If words are written in such a way that they could be read in more than one way – for example, as either exothermic or endothermic, then credit is not awarded. This also happens with numbers, 1 and 2 can be written in a similar way, so can 4 and 9. Credit is not awarded in such cases.
- If a candidate wishes to change an answer, they must cross out their original answer completely. If there is insufficient space to write their replacement answer, there is plenty of blank space on the question paper. A comment to identify where an answer is written should be included, such as ‘continued on page 5’.
- Answers to calculations should be given to a minimum of two significant figures but three significant figures are preferred or sometimes required. 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 three significant figures.
- In an extended calculation worth several marks, such as **Question 1(b)**, the explanation of the working is important.
- The questions on organic chemistry required formulae to be drawn. Candidates should use displayed, structural, or skeletal formula. Examples were seen where these types of formulae were mixed, and some skeletal formulae where either the carbon atoms, or the hydrogen atoms, but not both, were drawn in. Candidates should be strongly discouraged from taking this approach, which runs the risk of losing credit.
- Care should be taken when drawing curly arrows and labelling partial charges to show organic reaction mechanisms. A curly arrow should start clearly on a bond or on a lone pair and the arrowhead should point clearly in the direction of the destination of the electron pair. In electrophilic substitution mechanisms, the curly arrow in the first step should start on the circle within the hexagon and end at the positively charged electrophile. The curly arrow in the second step should start in the middle of the C–H bond that is about to break. It should end at the broken circle within the hexagon.

General comments

It is emphasised that both care and the correct following of convention is needed when writing the formulae of substances. In **Question 8(b)(ii)** care was needed to show the salts of the carboxylic acids as either $–COO^-Na^+$ or –COONa, but a mixture of these two approaches, i.e., $–COO^-Na$ and $–COONa^+$, lost credit.

The majority of candidates were able to work through to the end of the paper. Some candidates may have given up. This should be discouraged, as many candidates found parts of later questions, such as **Question 8** and **Question 9**, very accessible.

Many candidates had good ability to show the skills needed to answer an examination paper of this type. Better performing candidates showed good skills in:
- 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
- drawing the stages of a reaction mechanism.

Comments on specific questions

Question 1

(a) (i) This was answered well by many candidates. Some focused on charge density of the cation and the consequent distortion of the anion; this approach often gained partial credit.

(ii) Credit was very rarely awarded for this question. Many candidates made statements about 'more $OH^–$'. However, a high pH is due to a higher **concentration** of $OH^–$.

(b) This question discriminated well. Many candidates could work through as far as $[OH^–] = 0.0158\,mol\,dm^{–3}$ but got stuck at this point. Other candidates worked past this to a final answer of 0.679 g, gaining three marks. It is important to emphasise the large number of candidates who may have lost marks by not explaining their working. Examiners cannot award credit by picking unexplained numbers such as 0.0158 out of a candidate's response. Such numbers must be clearly identified, for example as '$[OH^–] = 0.0158\,mol\,dm^{–3}$'.

(c) (i) Credit was often awarded for this question. $K_{sp} = [Fe^{2+}][2OH^–]^2$ was a common incorrect answer.

(ii) This was answered well by many candidates.

Question 2

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

(ii) This was answered well by many candidates. The distinction between 'partly filled d-orbitals' in **Question 2(a)(i)** and 'empty d-orbitals' in **Question 2(a)(ii)** was important.

(b) (i) Most candidates gave a correct definition. Some candidates wrongly gave a definition of 'non-degenerate'. No credit was given for 'orbitals of similar energy'.

(ii) Most candidates could sketch the shape. The commonest error was to draw the lobes along the x and y axes, rather than between them.

(c) Many candidates found these equations particularly difficult. It should be noted that when NaOH(aq) is a named reactant it is extremely unlikely that HNO_3 will be a product of the reaction.

(d) Many candidates gained at least one mark. The deduction that the H–N–Ag bond angle is equal to or close to 109.5° was found difficult.

(e) This was found to be very difficult by many candidates. Many half-equations were seen that did not involve Ag^+ gaining electrons at the positive electrode, or Zn losing electrons at the negative electrode; such answers gained no credit.

(f) One mark was often awarded for a diagram in which N—N acts a bidentate ligand bonded to two different Ru^{3+} ions. Incorporating this knowledge into two repeat units of the polymer was more rarely awarded.

Question 3

(a) Very many unbalanced equations were seen. Some candidates ignored the information given in the question and submitted an equation that did not include a carbonate compound.

(b) It was very important for candidates to make it clear which substance, or ion, they were describing when answering this question. Statements such as 'ionic radius increases' or 'it has a greater ionic radius' could refer to any one of Ca^{2+}, Ba^{2+} or $C_2O_4^{2–}$. A statement such as 'ionic radius increases down Group 2 from Ca^{2+} to Ba^{2+}' or 'Ca^{2+} has a smaller ionic radius' is clear, unambiguous and correct. A significant number of candidates discussed the strength of attractive forces between the anion and the cation, rather than the polarisation of the anion by the cation.

(c) This was answered well by many candidates, who showed that they had prepared well for this type of question.

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

(e) Good quality three-dimensional diagrams that gained full credit were seen in many responses.

(f) It was common to see one correct equation, $HC_2O_4^- + H^+ \rightarrow H_2C_2O_4$. It was rarer to see $HC_2O_4^- + OH^- \rightarrow C_2O_4^{2-} + H_2O$. Many candidates wrote $H_2C_2O_4 + OH^- \rightarrow HC_2O_4^- + H_2O$. This is incorrect; the concentration of $H_2C_2O_4$ in the solution is too low to have an effective buffering action.

(g) Full credit was often awarded, although both the equation and the $E^\ominus_{cell}$ required care.

Question 4

(a) Full credit was often awarded. Errors seen included:
- describing the SHE as a cell, rather than as an electrode or a half-cell
- omitting the description of standard conditions.

(b) (i) This was answered very well. Some candidates omitted the liquid levels in the beakers or drew in liquid levels that would not touch the electrodes or salt bridge.

(ii) Although some excellent answers were seen, many answers referred to ‘the equilibrium’ or ‘the equation’ shifting to the left without specifying which equilibrium or equation they meant.

(c) Most candidates gave a correct definition. Weaker definitions ended with ‘…to form one mole of aqueous ions.’ When one mole of ionic solid is dissolved in water the **minimum** is that two moles of aqueous ions are formed.

(d) (i) This question discriminated well.

(ii) Some candidates omitted the minus sign.

(e) Although some excellent answers were seen, many candidates ignored, or were unaware of, the instruction in the syllabus to explain the effect of **ionic charge** and **ionic radius** on the numerical magnitude of lattice energy. Answers that did not focus on these two factors inevitably lost credit. Some answers focused on ionic radius only, ignoring the greater charge on Mg^{2+}.

Question 5

(a) (i) This was often correct. However, tangents were sometimes seen at other places on the curve, where the value calculated cannot be the **initial** rate of reaction.

(ii) This question was found to be difficult by many candidates. Many answers were seen that discussed limiting reagents; these gained no credit. The key to the explanation is that using a large excess of iodide ions keeps the concentration of iodide ions effectively constant, so that the rate of the reaction depends only on the concentration of persulfate ions.

(b) Many candidates were well prepared for questions based around this material. Errors included unbalanced equations and not including Fe^{2+} in equation 1.

(c) The effect was often correctly described.

(d) The half-life was usually correctly calculated.

(e) This discriminated well. Many candidates lost marks having written equations that were unbalanced for charge.

Question 6

(a) (i) This question discriminated well. A successful answer had four key components: ratio, concentrations, solute, solvents – that had to be found within a meaningful sentence.

(ii) Candidates found this very difficult. Firstly, it was necessary to calculate that there is 0.74 g of **X** in the 40 cm^3 of aqueous solution. Then the equation 10.5 = (y ÷ 25) / ((0.74 – y) ÷ 40) had to be written, where y is the mass in grams extracted into CS_2. Having done this, the equation needed to be evaluated.

(b) Full credit was often awarded. Some answers suggested that one or more of the structures contained more than six carbon atoms.

(c) This material is not well known by many candidates. 'C–C bonds are p bonds only' was a commonly seen part of many answers. Another issue was where candidates described s and p bonds without stating whether these bond types are found in C–C bonds or C–H bonds.

(d) This question was found to be difficult by many candidates. Very few answers were seen that recognised the significance of inter-bond repulsion to the stability of Dewar benzene and Ladenburg benzene.

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

(f) (i) The equation was often correct. However, care was needed to ensure correct copying of the formulae given in the question.

(ii) Some common errors included:

- showing the positive charge on the intermediate near to the sp^3 hybridised carbon atom, rather than in the centre of the hexagon
- drawing the start of the second curly arrow on the hydrogen atom, rather than on the C–H bond.

(iii) Very few candidates appreciated the ability of the terminal $–CH_2Br$ group to react with a second molecule of phenylethanone, or to react with the benzene ring of the initial product.

Question 7

(a) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(b) (i) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(ii) Please note that due to a series-specific issue with this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged.

(c) (i) This question discriminated well.

(ii) This question discriminated well. Many candidates thought that ester **C** would have a triplet peak in its proton (^1H) NMR spectrum. This is incorrect.

(d) This was a very demanding question requiring careful examination of the information given, systematic thinking and a thorough knowledge of A-level organic chemistry. The following points relate to errors seen on many scripts.

- Organic structures, using either displayed or skeletal formulae, should be drawn with care.
- Knowledge and the application of valency is of great assistance to candidates when answering such a question. Many three-valent or five-valent carbon atoms were seen.
- The question gives molecular formulae for compounds **F**, **J** and **K**. Those candidates who submitted answers as displayed formulae probably found it easier to check they had included the correct number of hydrogen atoms.
- When a positive iodoform test is performed, the yellow precipitate is CHI_3, not CIH_3.
- $LiAlH_4$ does not reduce a C=C double bond.
- When $SOCl_2$ reacts with a –COOH group the product is a –COCl group, not a –COOCl group.
- When a –COCl group reacts with propan-2-ol the ester formed has a $–COOCH(CH_3)_2$ group, not a $–COOCH_2CH_2CH_3$ group.

Question 8

(a) (i) Most candidates correctly stated the number of chiral carbon atoms.

(ii) The functional groups were usually identified. Commonly seen wrong answers included ketone and ‘carboxylic’ on its own, rather than ‘carboxylic acid’.

(b) (i) This question discriminated well.

(ii) This question was found to be difficult by many candidates. It required detailed knowledge of the chemistry involved. Care had to be taken when drawing structures. It should be noted that methanol does not react with hot NaOH(aq) to form $CH_3O^-Na^+$.

Question 9

(a) (i) The equation was usually correct. Wrong answers included unbalanced equations and equations with H^+ or H_2O as one product.

(ii) This question discriminated well. Incorrect answers included:

- structures with –NO or –NO_3 side groups
- structures without –OH groups
- two identical structures, such as two 3-nitrophenol molecules drawn as mirror images.

(b) This was found to be difficult, although some excellent answers were seen. Much care was required to show the structures correctly.

(c) (i) This was found to be difficult. It should be noted that to produce the three new bonds needed to form cyclohexene, the three curly arrows had to be either all clockwise, or all anticlockwise.

(ii) This was found to be difficult.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- There is no substitute for comprehensive practical experience in preparation for this paper. Although the actual experimental methods examined have often not been encountered, the general understanding gained by performing practical investigations is invaluable.
- The best starting point for answering the questions posed is an understanding of the practical aim and methodology, which is achieved by thorough reading and analysis of the information given in the paper, backed up with the widest range of prior experience possible.

General comments

Candidates gained a wide range of marks from 0 to 29 on this paper. Approximately the same number gained fewer than 10 marks as gained 20 or more. There were very few ‘no responses’ to question parts.

Comments on specific questions

Question 1

Candidates generally found this question to be very slightly less challenging than **Question 2**.

(a) (i) This calculation was performed correctly by most candidates. Some ignored the water of crystallisation associated with hydrated sodium thiosulfate $Na_2S_2O_3.5H_2O$, leading to an incorrect M*r* of 158.2 and the most popular incorrect final answer of 0.1582 g.

(ii) The candidates’ ability to identify apparatus that is suitable for conducting each step of a procedure has improved in recent series. Candidates should note that capacity must be specified when selecting volumetric apparatus.

(b) (i) Many candidates did not show the correct working and/or produce the correct answer.

The maximum uncertainty in a quantitative measurement is half the difference between the closest calibrations, i.e. ± 0.05 cm^3 in this case. To transfer 5.0 cm^3 alkaline aqueous potassium iodide using a syringe, two measurements are required i.e. 0.0 cm^3 and 5.0 cm^3.

The maximum percentage error in the measurement of 5.0 cm^3 = $\frac{2 \times 0.5}{5.0} \times 100$ = 20(.0%).

(ii) Many candidates were able to work out that the actual uncertainty of the measurement would remain the same, as the scale division has not changed, and the percentage error of the measurements would be smaller, as the volume measured is larger.

(c) (i) Very few candidates described both essential actions required to prepare a clean burette before taking any readings. Many described step 1 but very few step 2.

1. Rinse the burette with the titrant solution, making sure to let the solution coat the inside of the burette.
2. Fill the burette completely with titrant and run some of the solution through the tip (to ensure the tip below the tap is full of titrant).

(ii) Candidates struggled to describe the method involved in conducting an accurate titration. Responses relying on 'titrate' or 'titration' to describe the process invariably lacked the required detail. A 'rough' titration was not possible in this case as each sample was wholly used to conduct one accurate titration.

(d) Whilst it was clear to many candidates that mixing the reaction mixture causes the various species to be homogeneously distributed, the primary reason for the mixing is to ensure the reactions involved happen to completion.

(e) The majority of candidates were able to draw a suitable table for recording the results of this experiment. Some showed their lack of understanding of the method followed by including rough titration and/or an indication of which titres should be used for calculation of mean values. The whole of each sample is used for one accurate titration in this experiment.

(f) This calculation was performed successfully by candidates that performed well. Most were able to calculate the amount of sodium thiosulfate in the mean titre. Using this to calculate the concentration of dissolved oxygen successfully was more elusive. The most common errors occurred in the calculation of the amount, commonly multiplying by 4 (rather than dividing), and concentration of dissolved oxygen, commonly dividing by 0.05 instead of 0.03.

(g) (i) Some incorrectly thought the concentration value was greater than zero because some of the reactants contain oxygen in their formula. The answer that some of the aqueous reagents contained dissolved oxygen gas, was mentioned infrequently.

(ii) The sample of freshly distilled water can be used as a blank: its measured value is subtracted from that of the river water value to determine the concentration of oxygen in the test sample. There are multiple sources of extra dissolved oxygen in the determination as described in **(g)(i)**: the blank measurement determines the concentration of oxygen present from all other sources than the sample of river water itself. Some candidates used these ideas to answer this question correctly, whilst others incorrectly suggested using a mean or gave more general answers that did not describe the actual use of the value.

(h) The description of any valid reaction of chlorine with one of the reagents used gained credit in this part.

Question 2

This question generated slightly more problems for candidates than **Question 1**.

(a) A number of candidates were not able to suggest a valid reason. The establishment of the same desired temperature in both flasks is key.

(b) (i) Many candidates did not gain credit for this question. The temperature of the reacting mixture needs to be followed throughout the timed part of the reaction. The simplest way to do this is to measure at the start and end of the reaction i.e. when the contents of flasks **A** and **B** are mixed and when the black cross is no longer visible, and the timer is stopped. More measurements at time intervals for the whole of this period would enhance the procedure further but were not necessary for credit. A datalogger and temperature probe could also be used to do this automatically.

(ii) Determination of a mean of temperature measurements produces the best value to use as the temperature of the mixture during the reaction.

(c) Completion of Table 2.1 as instructed was accurately done overall. Candidates found the expression of values to four decimal places than to the nearest whole number more difficult.

(d) (i) The plotting of data points on the graph grid was carried out to an appropriate accuracy by most candidates. It is important to ensure that the centre of the point is clearly on or between grid lines. In this case, the line of best fit is a straight line that minimises the distance between it and the data points plotted. Any points candidates regard as anomalous should be clearly identified.

(ii) Expression of points and calculation of gradient was much improved on recent series. Most candidates listed (x, y) acceptable points, in the correct form and with a large enough range (at least half of the range of values), from the line of best fit and were able to express the correctly calculated gradient correctly to three significant figures.

(iii) The graph plotted in **(d)(i)** to show the relationship between log 1/*t* and 1/*T* is a straight line which is described by the equation given. The most straightforward way of completing this calculation successfully required recognition from this equation that that the gradient calculated in **(d)(i)** equalled $-E_A/R$. Many candidates did this and were able to calculate E_A. Units proved to be a problem for some. A small number of candidates used an alternative method involving calculation of the constant using a point on the line of best fit and then finding E_A using the full equation.

(iv) Most candidates answered this question correctly, recognising that the correctly plotted data obeys the line of best fit and there are no anomalous points and so is reliable.

(e) In order to make the time measured shorter, and the reaction faster, the concentration of either reactant could be increased. The question asks for a shorter time for a given temperature, so changing the temperature is not a valid option.

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Key messages

- Candidates need to be aware that when determining a gradient it is always better to select points from the line of best fit rather than from plotted data as data points are not necessarily on the line of best fit.

- Candidates need to be aware when to rinse apparatus during the transfer of solutions. If a solution is transferred from a beaker to a volumetric flask, then rinsing of the beaker is required. If a solution is transferred from specific volumetric apparatus such as a burette or a pipette, then no rinsing is required as both these pieces of apparatus are designed to transfer a stated amount of solution.

General comments

Wherever possible candidates should complete practical work throughout the course. **Question 1** was based on an AS Level experiment designed to determine the enthalpy change of reaction by an indirect means.

There was a significant number of numerical answers needed on this paper and candidates should be aware that at A level, answers should reflect the appropriate number of significant figures. Usually, most numerical answers, if not indicated otherwise, should be to three significant figures. One significant figure will almost certainly be insufficient.

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

Comments on specific questions

Question 1

(a) Candidates found this question challenging.

No enthalpy change can be measured directly, but the change in temperature usually can. However, in this case the temperature change caused by the reaction cannot be measured because calcium carbonate is being heated at the time.

Common imprecise responses included ‘heat loss’, ‘high temperature needed’ or ‘it is a solid’.

(b) (i) This question was very well answered by most and 5.01 g was a commonly seen answer, although some clearly missed the reference to a 2 decimal place balance in the question and gave 5.005 g as their answer.

(ii) Many candidates knew that the order of the two key readings were firstly the mass of the weighing boat with calcium carbonate in it, followed by the mass of the weighing boat after transfer of the calcium carbonate. This means that the true mass of calcium carbonate transferred is known and allows for any residual deposits left behind on the weighing boat after transfer.

Many did not understand the meaning of weighing by difference and assumed that simply weighing an empty boat followed by weighing the combined mass of the weighing boat and calcium carbonate would suffice. Some candidates appeared not to be familiar with the use of weighing boats and opted to use beakers or crucibles in place of weighing boats.

Nearly all candidates constructed a suitable table, although some did not include units. At A Level the term ‘mass’ is expected rather than the term ‘weight’.

(c) Although the HCl(aq) was in excess, a measuring cylinder, the choice of many candidates, was not suitable as it could not provide a volume to a second decimal place. A burette was required as the precise volume of HCl(aq) would lead to the *exact* mass of HCl(aq). This exact mass is needed in calculating the amount of energy produced by the reaction based upon the temperature increase.

(d) Most candidates realised that the two best ways to improve the accuracy of the experiment in steps 3 and 4 were either swirling the flask/stirring the contents or measuring the temperature more frequently.

(e) (i) Nearly all candidates plotted the points correctly, although a few overlooked the last four points.

The line of best fit for the data after 3 minutes was less successfully attempted as many did not extrapolate the line to 3 minutes (this was already done on the graph for the points before 3 minutes).

The common error from some candidates was to draw a second line from the point at 4 minutes through the anomalous point at 3.5 minutes to meet up with the line of best fit for the data before 3 minutes.

(ii) Of those candidates who extrapolated their line of best fit back to three minutes, many simply gave the projected temperature at 3 minutes rather than the theoretical temperature increase at 3 minutes.

(f) Most candidates suggested correctly that the reaction had not finished at 3.5 minutes, although a few referred to dissolving rather than reacting.

Many incorrect answers were based on the theme of a delay/time lag in the temperature rise.

(g) Most candidates were able to use the equation given, $q = mc\Delta T$ to determine q.

Common errors for determining q included:

- attempting to convert the temperature change to Kelvin by adding 273
- taking the mass of HCl(aq) to be 1 g.

Converting q to ΔH_2 proved more problematical. Many overlooked that the HCl(aq) was in excess and forgot to scale up to molar quantities by using 0.100 mol (the moles of HCl present) instead of 0.0500 mol (moles of CaO used).

Some candidates, having successfully calculated a value for ΔH_2, did not appreciate a negative sign was needed as the reaction was exothermic.

(h) This Hess's cycle proved to be a very challenging question.

Having been given ΔH_1 (–84 kJ mol^{-1}), ΔH_r is calculated by subtracting the value of ΔH_2 (the answer to **1g**) from –84. Higher performing candidates correctly wrote –84 – (–259) = +175 kJ mol^{-1}.

The use of the assumed value for ΔH_2 given in the question (179 kJ mol^{-1}) was deliberately not given a sign. Thus, candidates here too had to apply a minus sign as the reaction in **(g)** was exothermic.

(i) Many candidates gained full credit for the idea of heat loss being the main weakness and introducing insulation whether by using a lid or by using a Styrofoam cup as the improvement.

Some candidates opted to improve insulation by sealing the container with a bung. This was not acceptable as one of the products is a gas.

Question 2

(a) The three key points of making up a standard solution from a solution of known concentration were known by most candidates. These were:

- Calculating the volume of solution **A**, 0.00920 mol dm^{-3} $SCN^-(aq)$, required to form 100 cm^3 of solution **B**, 0.00200 mol dm^{-3} $SCN^-(aq)$. The expected volume was 21.75 cm^3. This point was often correct.
- Transferring 21.75 cm^3 of solution **A** using suitable volumetric apparatus (i.e. a burette) into a volumetric flask. This point was found to be more challenging.
- Topping the solution in the volumetric flask up to the 100 cm^3 mark with distilled water and shaking to achieve a homogenous mixture. This point was often correct.

Common errors in transferring solution **A** included:

- Stating the volume of solution **A** to be transferred by burette was 21.74 cm^3. (Burettes can only measure to nearest ±0.05 cm^3).
- Using non-volumetric apparatus, usually a measuring cylinder, to measure the volume of solution **A**.
- Using non-volumetric apparatus such as a beaker or conical flask instead of a volumetric flask to place this volume of solution **A**.
- Adding rinsings from the burette to volumetric flask.

Many candidates opted to transfer from a burette into a beaker as an intermediate step. Although unnecessary, this was not penalised if the rinsings of solution **A** were transferred to the volumetric flask from the intermediate beaker.

Common errors in topping the solution in the volumetric flask up to the 100 cm^3 mark included:

- Not using *distilled* water when topping up the volumetric flask.
- Topping up to a volume other than 100 cm^3. (250 cm^3 was common).

Candidates who transferred 21.75 cm^3 (or 21.74 cm^3) of solution **A** did not receive credit for saying 'add 78.25 cm^3 (or 78.26 cm^3) of distilled water to the volumetric flask'.

(b) A number of candidates knew that **D** was in excess to force the equilibrium as far right as possible, so that all **B** had reacted and consequently the concentration of $FeSCN^{2+}(aq)$ is known.

(c) (i) Most candidates were able to identify the dependent variable as (relative) absorbance.

(ii) The most common answer here was to use a thermostatically controlled water bath. This was credited as these water baths do go down to 10 °C. The expected, more practical answer of 'add ice' was seldom seen.

Common answers which were not credited included: use a water bath, use cold water, use the air conditioning and even *heat* to 10 °C.

(d) (i) Most candidates correctly read the calibration graph, although some did not give the answer to one decimal place. A few did not read the heading of the column and incorrectly included × 10^{-5} in their answer.

(ii) Most candidates correctly applied the equation and provided correct values in column 4. The common errors in the calculation of K_1 were either incorrect rounding or not giving answers to the nearest whole number.

(e) (i) A number of candidates realised that the graph, being a straight line, supported the relationship in equation 2, that **log** K_1 was proportional to 1/T.

A common error was to state that the graph showed a proportionality between K_1 and T.

(ii) The anomalous point was identified by most candidates. The reason for the anomaly was less readily understood. Given that they were told it was not an error in measurement, most candidates found it very hard to reason the anomaly without discussing a measurement. Higher performing candidates suggested that 'the reaction was not complete' or 'had not reached equilibrium' or 'not all solution **B** had been transferred'. Other creditworthy responses included the idea that the 'concentration of $FeSCN^{2+}(aq)$ was too low' or 'the cuvette was not cleaned'.

(iii) Most candidates coped very well with the reading of co-ordinates and subsequent calculation of the gradient.

For some, the different scales on the *y* and *x*-axes caused some errors in reading the co-ordinates especially on the *x*-axis. A relative few gave reversed (y, x) co-ordinates. Some opted for co-ordinates which are too close together.

Candidates who performed less well chose to attempt to select co-ordinates of the points plotted rather than from the line drawn.

The two common errors were in the calculation of the gradient. Either:
- not providing answers to 3 significant figures
- incorrect rounding.

(iv) The majority of candidates successfully used their gradient value to calculate ΔH. A very small minority gave an incorrect sign and there were some who omitted to convert their answer from J to kJ. A common error was to maintain the constant in the gradient equation and use a point from the plot in addition to the gradient to achieve their answer.

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Key messages

- There is no substitute for comprehensive practical experience in preparation for this paper. Although the actual experimental methods examined have often not been encountered, the general understanding gained by performing practical investigations is invaluable.
- The best starting point for answering the questions posed is an understanding of the practical aim and methodology, which is achieved by thorough reading and analysis of the information given in the paper, backed up with the widest range of prior experience possible.

General comments

Candidates gained a wide range of marks from 0 to 29 on this paper. Approximately the same number gained fewer than 10 marks as gained 20 or more. There were very few 'no responses' to question parts.

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