CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Questions 4, **5**, **14**, **17**, **18**, **20**, **27**, **29**, **30** and **39** were found to be the easiest.

Many candidates found **questions 1, 12**, **13**, **22**, **28**, **35** and **38** to be particularly difficult. These are reviewed below.

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Comments on specific questions

Question 1

The most common incorrect answer was **A**. Option **A** cannot true. For example, if element Y is sodium and element X is chlorine, the atomic radius of the elements decreases across period 3. Option **B** is correct because the lowest possible value for the atomic number of element Y is 1 and X is 7, so the n=1 shell of element X must be full.

Question 12

The most common incorrect answer was **D**. If the answer is **D**, then element E is chlorine. The 8th IE of chlorine is much greater than the 7th IE. The data in the question does not match this statement. Element E is silicon, which has four outer electrons in the 3rd shell. Once lost, the 5th, 6th, 7th, and 8th electrons are all lost from the 2nd shell and would have comparable IE's. The data in the question matches this statement, so the answer is **A**.

Question 13

The most common incorrect answer was **B**. The data in the question can be used to calculate that 0.070 mol of Mg and 0.11 mol of HCl is present. This means that HCl is the limiting reagent as 0.070 mol of Mg would react with 0.14 mol of HCl as per the balanced equation. In this reaction 0.055 mol of H_2 gas is produced. Under the conditions described in the question 0.055 mol of gas occupies a volume of 1.3 dm^3 when given to two significant figures.

Question 22

The most common incorrect answer was **A**. ICl and Br_2 have very similar instantaneous dipole-induced dipole forces, as both molecules have 70 electrons, so the answer cannot be **A** or **C**. IBr does not have stronger permanent dipoles than ICl as Cl is more electronegative than Br, so the answer is **B**.

Question 28

The most common incorrect answer was **B**. Since the hydrocarbon is 14.3% H, it must be 85.7% C. Calculation shows the hydrocarbon has an empirical formula of CH_2. Since the hydrocarbon reacts with bromine by addition, it must be an alkene and have one C=C bond per molecule. This means one Br_2 molecule reacts with one hydrocarbon molecule. Since 0.799 g of Br_2 contains 0.005 mol, 0.280 g of the hydrocarbon must also contain 0.005 mol, so the M_r of the hydrocarbon is 56 and the molecular formula is C_4H_8. The answer is **C** and the four alkenes with this M_r are:

- but-1-ene
- cis but-2-ene
- trans but-2-ene
- methylpropene

Question 35

The most common incorrect answer was **B**. Most candidates knew that reaction 2 requires a reducing agent that will reduce a carbonyl group to an alcohol. Acidified sodium dichromate(VI) cannot be used for reaction 1 as it will oxidise the alcohol group to a ketone. This means that the correct answer is **D**.

Question 38

The most common incorrect answer was **B**. **A** and **B** can be ruled out since ester Z does not have one or more -O-C_2H_5 groups. The best way to confirm that the X and Y given in **C** can react to form ester Z is to draw out the skeletal structure for Y. If the two -OH groups esterify with ethanoic acid, ester Z is produced.

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Paper 9701/12
Multiple Choice

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

General comments

Questions 1, **4**, **8**, **16**, **22**, **25**, **29**, **35** and **40** were found to be the easiest.

Many candidates found **questions 14**, **15**, **18**, **23**, and **28** to be particularly difficult. These are reviewed below.

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Comments on specific questions

Question 14

The most common incorrect answer was **C**. Since the partial pressure of hydrogen at equilibrium is 4.00×10^3 Pa, and one molecule of iodine forms when one molecule of hydrogen forms, the partial pressure of iodine at equilibrium is also 4.00×10^3 Pa. Since the total pressure at equilibrium is 1.20×10^5 Pa the partial pressure of hydrogen iodide at equilibrium is 1.12×10^5 Pa ($1.20 \times 10^5 - (2 \times 4.00 \times 10^3)$). Using the equilibrium expression for the decomposition of hydrogen iodide gives a value for K_p of 1.28×10^{-3}.

Question 15

The most common incorrect answer was **A**. This suggests that most candidates were able to work out that statement 1 explains the difference while statement 3 does not. Statement 2 is true but does not explain the difference.

Question 18

The most common incorrect answer was **B**. From sodium to phosphorus the value of z:y is 1, 2, 3, 4, then 5, so it shows a steady increase. From sodium to phosphorus the value of q:p is 0.5, 1, 1.5, 2 then 2.5, so it also shows a steady increase.

The choice of **B** by many candidates suggests that the formulae of the chlorides of Na, Mg, Al, Si and P are better known than the formulae of the oxides of these elements. It is certainly easier to deal with the ratio z:y since all its values are whole numbers.

Question 23

The most common incorrect answer was **B**. This suggests that most candidates were able to work out that ammonium nitrate has a higher percentage of nitrogen than ammonium sulfate does. Since the ammonium ion is a proton donor it is a weak acid, so the correct answer is **A**.

Question 28

The most common incorrect answer was **A**. The nine products are:

* chloroethane
* 1,1-dichloroethane and 1,2-dichloroethane
* 1,1,1-trichloroethane and 1,1,2-trichloroethane
* 1,1,1,2-tetrachloroethane and 1,1,2,2-tetrachloroethane
* pentachloroethane
* hexachloroethane

The choice of **A** by many candidates suggests that the products considered were chloroethane, 'dichloroethane', 'trichloroethane', 'tetrachloroethane', pentachloroethane and hexachloroethane only.

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Paper 9701/13
Multiple Choice

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

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

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

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

General comments

Questions 1, **5**, **9**, **10**, **14**, **18**, **20**, **21**, **23**, **30** and **37** were found to be the easiest.

Many candidates found **questions 2**, **7**, **31**, **32**, **36** and **40** to be particularly difficult. These are reviewed below.

Please note that due to an issue with **question 19**, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

Question 2

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

The equation on the question paper is: $u\text{MnO}_4^- + v\text{H}^+ + w\text{I}^- \rightarrow x\text{Mn}^{2+} + y\text{H}_2\text{O} + z\text{I}_2$

The correctly balanced equation is: $2\text{MnO}_4^- + 16\text{H}^+ + 10\text{I}^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{I}_2$

The value of v is 16. Candidates who chose answer B believed v to be 8. This would mean z is 2.5. It is stated in the question that u, v, w, x, y, and z are all whole numbers, so **B** is incorrect.

Question 7

The most common incorrect answer was **C**. Most candidates knew that ideal gases are assumed to have no intermolecular forces. There was uncertainty over whether ideal gas molecules are assumed to have no mass or no volume. No volume is correct.

Question 31

The most common incorrect answer was **A**. The nine products are:

- chloroethane
- 1,1-dichloroethane and 1,2-dichloroethane
- 1,1,1-trichloroethane and 1,1,2-trichloroethane
- 1,1,1,2-tetrachloroethane and 1,1,2,2-tetrachloroethane
- pentachloroethane
- hexachloroethane

The choice of **A** by many candidates suggests that the products considered were chloroethane, 'dichloroethane', 'trichloroethane', 'tetrachloroethane', pentachloroethane and hexachloroethane only.

Question 32

The most common incorrect answer was **A**. From this we can deduce that many candidates were confident that Y does not have stereoisomers, but were less sure about X. After the addition of Br_2 to 1-methylcyclohexene, product X shows cis/trans isomerism and has two chiral carbons at positions 1 and 2 in the ring. This gives a total of 2 + 2 = 4 stereoisomers.

Question 36

The most common incorrect answer was **D**. Many candidates also incorrectly chose **A** and **C**. Compound B is hydrolysed to give $\text{CH}_3\text{CO}_2\text{H}$ and $\text{HOCH}_2\text{CH}_2\text{CO}_2\text{H}$, both of which have the empirical formula CH_2O. Compounds B and C do undergo hydrolysis but they both produce two products with differing empirical formulae. Compound D cannot be hydrolysed by $\text{HC}l(\text{aq})$.

Question 40

The most common incorrect answer was **C**. Peaks M and M+2 are of equal height, so compound X is a bromine compound. The correct answer must be **C** or **D**. To deduce the number of carbon atoms in a compound the formula from 22.2.5 in the syllabus is required. $100 \div (1.1 \times 15)$ gives the answer 6.06, so there are six carbon atoms per molecule. This confirms the correct answer as **D** and not **C**.

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Paper 9701/21
Paper 2 AS Structured Questions

Key messages

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

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

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

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

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. Candidates showed themselves able to perform on both AO1 and AO2 items, though there were some notable relative weaknesses.

Candidates should consider whether they need to write at greater length than the space given for answers; longer answers are often less clear or even contradictory. Where candidates find it necessary to write at greater length than the space provides, they should be reminded to give a clear indication of where their continued writing can be found.

Comments on specific questions

Question 1

(a) This was generally well answered. Some candidates were not familiar with the term nucleon number, often interpreting this as neutron number.

(b) Many candidates answered this question correctly. Common errors included not specifying **1**s and giving 5p as the answer.

(c) Candidates generally answered this well. State symbols were not always included, especially in Te^+.

(d)(i) The majority of candidates correctly identified two factors. Many candidates incorrectly stated that the shielding effect remains constant. An 'increase in nuclear charge' was a common incorrect response that negated other descriptions.

(ii) Most candidates recognised a general increase in successive ionisation energies, with a majority of those able to indicate the most significant jump from the 6th to 7th ionisation energy. Many answers incorrectly included a graph with a dip, most often in energy at the $6/7^{th}$ ionisation energy.

(e) Candidates who correctly referenced spin-pair interactions gained credit. Few candidates could use the VSEPR theory correctly.

(f) (i) This was generally not answered well. Many responses included a mixture of numbers and 'x's. A small proportion of candidates gave a correctly balanced equation.

(ii) Many candidates correctly identified this as a 'hydrolysis' reaction. A common answer was 'displacement', which was not enough to gain credit.

Question 2

(a) Some candidates were able to give a concise and accurate definition. Overall, the recall of this definition was not well attempted. Candidates often omitted any reference to a molar scale, although 'one mole of acid reacting with one mole of base' was commonly seen as an inadequate response. A common misconception was that neutralisation <u>requires</u> energy.

(b) (i) Few candidates were able to incorporate the relevant stoichiometry involved into their calculations.

(ii) Very few candidates gained full credit here. A very small proportion of candidates correctly used 175 g as the correct mass, many instead quoting 1 g. Many candidates converted the temperature to Kelvin but erroneously adding 273 to 7.8. A very small proportion of candidates correctly divided the energy released by the number of moles of water formed.

(c) (i) This was well answered by most candidates. Most were able to provide a correct balanced equation. Some gave the incorrect state of barium sulfate.

(ii) Many candidates stated that $BaSO_4$ is insoluble, though not many were able to link this to an additional energy change. Several answers incorrectly referred to the solubility of $Ba(OH)_2$.

Question 3

(a) Very few candidates could state the appearance of $SiCl_4$ at room temperature; more were able to state the correct structure and bonding. The most common incorrect response was giant covalent.

(b) Most candidates correctly referred to the appearance and pH. Candidates often did not refer to the relevant observation and struggled to differentiate the behaviours of the two chlorides.

(c) (i) A large number of candidates stated the correct reagent. Many left out aqueous or dilute as the conditions.

(ii) Many of the candidates defined disproportionation; a small proportion were able to refer to the correct oxidation numbers. Several referred incorrectly to the +1 oxidation number for chlorine.

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

(ii) Most candidates correctly answered the initiation step. Many candidates found the propagation and termination steps more challenging.

(e) This was well answered by most students.

(f) Many candidates were able to give the correct formulae at m/e = 164. Very few candidates gave both of the correct options at m/e = 166.

Question 4

(a) (i) Common errors were to retain the COOH group and to have the C=C double bond reduced.

(ii) This was well answered by most candidates.

(b) (i) This was generally well answered, although few candidates stated all the required conditions.

(ii) This was well answered by most candidates.

(iii) A small proportion of candidates gained full credit here.

(c)   Many candidates correctly gave pentan-1-ol. A small number of candidates made the link between the yellow precipitate with alkaline $I_2(aq)$ and a $CH_3CH(OH)-$ group. Many candidates struggled to synthesise all the detail to present a cogent answer to the question.

Question 5

(a) (i)   This was well answered by most candidates, although balancing the equation proved challenging for some.

   (ii)   Most candidates correctly mentioned the production of CO instead of CO_2. A very small number correctly referred to C and unburnt hydrocarbons.

(b) (i)   A large proportion of candidates incorrectly interpreted this as a question about catalytic converters. Many answers used NO instead of N_2.

   (ii)   A small number of candidates correctly identified the catalytic role of NO_x and gave all the relevant equations. Many gave the equation for the formation of H_2SO_4, and a significant number gave equations and answers related to the formation of HNO_3 for acid rain.

   (iii)   This was well answered by most. Some candidates gave the identity of a gas instead of the type of air pollution.

(c) (i)   Candidates often omitted dilute/(aq) with a named acid here.

   (ii)   A few candidates recognised that all three ester groups will undergo hydrolysis to form propanetriol. Many answers gave fragments where only one ester group had undergone hydrolysis.

   (iii)   This was well answered by most candidates. The majority of answers referred to esterification/substitution instead of condensation.

   (iv)   A small proportion of candidates answered this question correctly.

   (v)   A small proportion of candidates answered this question correctly.

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Key messages

The appropriate use of key terms and vocabulary is essential for a candidate to demonstrate full understanding of the subject. Candidates should be reminded to take care with similar sounding chemical terms as they can change the meaning of a statement; for example, use of 'nucleon' instead of 'nuclear' or 'isotope' instead of 'isomer'.

General comments

By convention, chemical equations should be balanced and use either → for a reaction which goes to completion, or ⇌ for a reaction in equilibrium. Candidates should be discouraged from using = when writing equations. Care should be taken to show chemical symbols correctly to avoid ambiguity; for example, CU represents carbon and uranium, but Cu represents copper.

Comments on specific questions

Question 1

(a) (i) It was generally well known about the bonding present in both species. Occasionally, candidates incorrectly described the bonding in magnesium as ionic.

(ii) The majority of candidates knew that the higher melting point seen for sodium chloride occurred because of stronger ionic bonds. Some candidates identified that there was a difference in bond strength between the two solids without using the information in the table to identify which had the stronger bond.

(iii) Many candidates were able to explain the difference in melting point in terms of the relative strength of intermolecular forces present. Stronger candidates identified the type of intermolecular forces involved and accounted for the difference in terms of the numbers of electrons present in molecules of sulfur and phosphorus. Some candidates incorrectly explained the difference in melting point being due to the difference in strength of covalent bonds.

(b) (i) This definition was generally well known. Some answers were incomplete or did not identify an atom as the appropriate species involved.

(ii) Many candidates knew that the outer electrons become more strongly attracted to the nucleus. Stronger candidates explained this effect in terms of the change in nuclear charge and the effect of shielding across the period.

(iii) It was generally well known that a hydrogen bond is the strongest intermolecular force present between ammonia molecules.

(iv) Stronger candidates were able to correctly show the role of the lone pair of electrons on the nitrogen atom in the formation of a hydrogen bond between ammonia molecules. Of those, some represented the attraction as a dative covalent bond with an arrow from the lone pair. Identification of appropriate partial charges in diagrams was seen more often. A common misconception showed two hydrogen bonds present between a pair of ammonia molecules to represent a dimer.

(v) The majority of candidates described the increased strength of a hydrogen bond in water and many accounted for the increased strength of the hydrogen bond by describing the difference in electronegativity between atoms of nitrogen and oxygen. A much smaller proportion of candidates also correctly referred to the different number of hydrogen bonds per molecule.

Question 2

(a) (i) The maximum oxidation numbers of the Period 3 chlorides were well known.

(ii) The majority of responses were correct. Some candidates produced responses that were vague and incomplete. Occasionally, explanations were incorrectly given in terms of changes to the nuclear charge.

(b) (i) The majority of candidates identified the correct formula of the silicon chloride and gave an appropriate balanced equation for the reaction.

(ii) A significant proportion of candidates incorrectly described the pH of the solution as greater than or equal to 7.

(c) (i) The equation to represent the reaction for phosphorus(V) chloride with water was less well known than the equation for **(b)(ii)**. The production of phosphorus oxide rather than phosphoric acid was a common incorrect answer. Other equations which showed appropriate species were not correctly balanced.

(ii) Many candidates gave appropriate suggestions for the pH of the solution produced in **(c)(i)**.

(d) (i) Equations using Cl rather than Cl_2 and production of O_2 with HCl were common incorrect answers.

(ii) A small proportion of candidates identified all the correct species and produced a balanced equation. Some candidates found the equation for the reaction of chlorine with hot NaOH(aq) to be demanding.

(e) (i) A wide range of incorrect species were seen in the answers; many of which were not ions.

(ii) Many correct equations representing this reaction were seen. Occasionally, equations gave incorrect multiples for the correct species which included the decomposition of some hydrogen peroxide without the use of sodium chlorate(I).

(iii) A significant proportion of candidates used the appropriate data to calculate the number of moles of sodium chlorate(I) used in a single titration. Difficulties arose in attempts to work out the concentration in the original sample, **W**. Occasionally, concentrations were left in mol dm^{-3} rather than converting this into g dm^{-3}, as detailed in the question.

Question 3

(a) (i) Some candidates incorrectly described the reagent and conditions required to convert carbonyl compounds to hydroxynitriles, rather than halogenoalkanes to nitriles.

(ii) The systematic name for **X** was not always used, e.g. propionitrile or ethyl cyanide. Omission of the 'e' in propanenitrile was often seen.

(iii) It was generally well known that this type of reaction is a hydrolysis reaction.

(iv) Many candidates correctly produced equations representing the production of hydrogen gas. The formula of the calcium salt was frequently given in terms of calcium with a valency of one.

(b) Many candidates knew that acidic conditions were required. Stronger candidates appreciated that the essential condition for this reaction was 'heat under reflux' to ensure complete oxidation to the carboxylic acid.

(c) Most candidates described the correct number of pi bonds present in **X**; the correct number of sigma bonds was seen less frequently. Seven, nine and ten sigma bonds were common incorrect answers.

Question 4

(a) Stronger candidates showed clear logical working and selection of appropriate data. Common errors included mis-reading the table, using an inappropriate value for a correctly identified bond, or ignoring the C-O bond during the reaction.

(b) Reference to the effect of increasing pressure on the amount of ethanol produced at equilibrium was not always included. Many explanations were given in terms of the change producing a shift to the position of equilibrium to the right; the significance of producing a smaller amount of gas to explain this change was mentioned less frequently.

(c) (i) Many candidates were able to deduce the behaviour of H_3PO_4 as an acid or an electrophile. Some explanations were not specific to step 1 in the reaction.

(ii) Some candidates were able to identify the correct species in step 2. Explanations were often vague, for example, 'seeking electrons' or 'being attacked by a pair of electrons' rather than 'accepting a lone pair'.

(iii) A small proportion of candidates applied knowledge of the drawing of mechanism arrows to represent electron movement when bonds are made and broken in this unfamiliar context. A common error showed arrows pointing in the opposite direction to the way an electron pair moves when a bond is made or broken. Sometimes an arrow did not start from the bond being broken or from the lone pair of electrons on an atom that is used to make a specific bond.

(iv) It was generally well known how a catalyst affects a reaction. Some ambiguity was seen in answers that described the effect of catalysts as increasing the number of collisions between particles rather than increasing the frequency of successful collisions.

(v) Stronger candidates clearly described the regeneration of the catalyst. Some candidates were vague and imprecise, for example 'the catalyst did not change in the reaction'.

(vi) Some candidates showed an excellent understanding of the consequence of more alkyl groups present on the C+ of the intermediate in terms of a larger inductive effect. Some candidates incorrectly referred to the inductive effect of propan-2-ol rather than the carbocation intermediate which was responsible for the production of propan-2-ol.

(d) The sideways overlap of two p orbitals to form a pi bond between the two carbon atoms was well known. Descriptions of the formation of the sigma bond by direct overlap of sp^2 hybrid orbitals were less common.

Question 5

(a) This definition was generally well known.

(b) (i) Many candidates appreciated that the two molecules were members of the carbonyl functional group. Some candidates incorrectly referred to them as either aldehydes or ketones.

(ii) Correct structures of **A** were common. Many candidates represented **B** as a ketone; the correct carbon skeleton was not always deduced.

(c) (i) It was common for some of the information in the question to be used to produce partially correct structures. Many candidates incorrectly produced structures with two types of stereoisomerism.

(ii) This was generally well answered.

(d) (i) Ketone and carboxylic acid were the most common incorrect answers.

(ii) Hydrolysis was a common incorrect response.

(iii) Deduction of the structure of **D** proved to be demanding. Often the structure drawn had a carboxylic acid group at one end of the molecule; identification of $(CH_3)CH(OH)–$ at one end of the molecule was seen less frequently. Occasionally, the correct ends of the molecule were drawn with an incorrect number of carbon atoms in the carbon backbone.

(iv) Stronger candidates clearly identified two differences between the spectra in terms of the different absorption ranges produced as a result of the different environment of the C=O bond in an ester compared to a carboxyl group, or in terms of the presence of the O-H bond in a hydroxyl or carboxyl group which is absent in the ester, **E**. Reference to absorbance at 2850 – 2950 due to C-H bonds was common, even though both **D** and **E** contain this type of bond.

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Paper 9701/23
Paper 2 AS Level Structured Questions

Key messages

*   Candidates should ensure they know how to correctly complete mechanisms, especially how to use curly arrows and what they represent.
*   It is important that candidates give accurate definitions and descriptions of chemical concepts.

General comments

Candidates should be discouraged from using non-standard abbreviations as they do not necessarily represent standard scientific terminology and are open to interpretation e.g. SE, which may be interpreted as meaning the shielding effect.

Comments on specific questions

Question 1

(a) (i)   A high proportion of candidates knew that copper is metallic. Many candidates omitted that the lattice is giant.

(ii)   Diagrams showing the metallic bonding as an array of positive metal ions surrounded by delocalised electrons were varied, with many either omitting or not correctly labelling the positive ions and delocalised electrons.

(b) (i)   Some candidates incorrectly referred to a mole of ^{12}C atoms or just an atom of ^{12}C.

(ii)   Many correct answers were seen. Some candidates omitted the word 'average'.

(iii)   The question was quite well answered. The major error included the use of 63 and 65 as the masses of the copper isotopes instead of the data given in the question.

(c)   Very few candidates recognised that the ion with an abundance of 23% and an m/e of 31.5 was that of $^{63}Cu^{2+}$.

(d) (i)   The equation was not well answered overall. Few candidates recognised that it was a redox reaction. Many answers contained electrons on one side of the equation and/or were completely unbalanced.

(ii)   The identification of Cu^{2+} as the oxidising reagent in this reaction was generally not well known. Many candidates answered with just 'copper'.

(iii)   The full electronic configuration of Cu^{2+} was frequently incorrect with the $4s^2$ electrons still present in many answers.

Question 2

(a) (i)   Many candidates knew that aluminium objects covered in a layer of aluminium oxide do not react with cold water because the aluminium oxide is insoluble in water and does not react with the water.

(ii) The equation, with state symbols, was quite well answered, with many candidates recognising that the product was aqueous sodium aluminate.

(iii) Some good answers were seen.

(b) Some candidates gave the formulae of nitrates of elements that are not located in Period 3.

(c) (i) Several candidates correctly stated the oxidation number of Al in $AlCl_3$. The answers for that of P in PCl_5 were varied.

(ii) Many candidates knew that Al and P had different numbers of electrons available to use. Many omitted where these electrons are located.

(iii) It was well recognised that PCl_5 was the required chloride of phosphorus and that HCl is a product of this reaction. Few candidates gave the correct product containing phosphorus. Many answers contained an oxide of phosphorus and/or an incorrect phosphoric acid.

(iv) Some candidates knew the reaction is a hydrolysis reaction with other candidates correctly describing it as a substitution reaction.

(v) Some good answers were seen.

Question 3

(a) Many candidates incorrectly stated, 'enthalpy change when 1 mole of acid reacted with 1 mole of base'.

(b) (i) Many candidates calculated the initial amount of H_2SO_4 instead of calculating the amount of acid that was neutralised by the NaOH.

(ii) Very few candidates deduced that Q = 5710 J and the mass of the solution was often incorrectly given as either 1.00 g or a number derived from calculating the masses of NaOH and H_2SO_4 in the reaction.

(c) (i) Some good answers were seen.

(ii) Several candidates knew that CH_3COOH was not fully dissociated, as it is a weak acid, compared to the strong acid HCl, which resulted in a less negative value for the $\Delta H_{neut.}$ Very few candidates knew that the difference in values of the respective ΔH_{neut} values was due to the additional energy required to fully dissociate the weak acid such that less energy is released after neutralisation.

Question 4

(a) (i) Some good answers were seen.

(ii) Very few candidates knew that hydrogen iodide is not prepared in the same way as hydrogen chloride because the hydrogen iodide and concentrated H_2SO_4 would undergo a redox reaction to form a variety of products to include SO_2, H_2S and I_2.

(b) (i) A small number of candidates recognised that when a sample of colourless HI(g) is placed in a sealed container and allowed to reach equilibrium the colour changes to purple, attributed to the formation of $I_2(g)$.

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

(iii) The calculation of the concentration of iodine in an equilibrium mixture was generally not well answered. Candidates who deduced that [HI] is (1.70 ÷ 2 =) 0.85 mol in the equilibrium mixture tended to gain some credit. Very few used the expression $\sqrt{(0.0217 \times 0.85)}$ to calculate the $[I_2]$ as 0.125 mol dm^{-3}.

(c) (i) Some candidates were able to describe the difference in composition of the equilibrium mixture at the two temperatures.

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(ii) Some candidates deduced that the reaction is endothermic in the forward direction leading to a lower concentration of H_2 and I_2 in the equilibrium mixture.

Question 5

(a) Some candidates deduced the correct empirical formula of C_3H_7O from a molecular formula of $C_6H_{14}O_2$.

(b)(i) Very few candidates used molecular formula, as required in the question, to construct an equation for the reduction reaction.

(ii) Many answers correctly stated that a suitable reducing agent for the reaction is $LiAlH_4$.

(c) Some good answers were seen.

(d) Many candidates correctly stated that **X**, the ketoacid, would react with all three reagents to give effervescence, an orange precipitate and yellow precipitate respectively. Fewer candidates recognised that the diol, **Y**, would only react with the alkaline $I_2(aq)$ as it contained a $CH_3CH(OH)$ moiety.

Question 6

(a) The single repeat unit derived from the monomer, $CH_2=CHCN$, by addition polymerisation was quite well answered.

(b)(i) Many candidates recognised that the mechanism for step 1 was nucleophilic addition.

(ii) Overall, the mechanism for step 1 was generally not answered well. The polarity on the C=O bond was often absent and the arrow from the CN^- to the C (in the C=O bond) did not start from the lone pair on the C of the CN^- ion. Several answers contained an incorrect intermediate with a positive charge which was then attacked by the CN^- nucleophile and many answers incorrectly showed an arrow from an H^+ ion to an O^- (in the intermediate).

(iii) Some good answers were seen.

(iv) The absorptions in the infrared spectrum of $CH_2=CHCN$ were often correctly identified as $C\equiv N$ and C=C. Incorrect answers mainly contained an identification of the functional groups rather than the bond or identifying the absorption (annotated as T on the IR spectrum) as that of a C=O group.

(c)(i) Very few candidates gave an accurate description.

(ii) A number of answers were awarded some credit. Few candidates were able to give a full description.

(d) Several candidates gave a correct pair of molecules that were non-superimposable images of $CH_3CH(OH)CN$. A common error was diagrams containing the same type of bond at 180° to each other.

(e) The equation for the reduction of propanenitrile to propylamine using hydrogen gas was not well known. Few candidates used the correct stoichiometry for hydrogen.

(f)(i) It was well known that the name of the type of reaction in step 1 is substitution.

(ii) Many candidates gained credit for ammonia. Many omitted heat or the solvent as conditions.

CHEMISTRY

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Paper 9701/31
Paper 3 Advanced Practical Skills
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Key messages

Candidates with experience of practical chemistry tended to do well in this paper. Candidates should be encouraged to:
- Read the questions carefully and prepare tables for recording data before commencing practical work.
- Use the Periodic Table, data section and Qualitative analysis notes at the back of the question paper.
- For qualitative work, present results clearly and use the correct terminology.

General comments

This practical paper contained questions using techniques that were familiar to most of the candidates. It was evident that some candidates had only limited practice in some of the techniques and in discussing the chemical principles on which the question depended. This led to a wide spread of marks.

Candidates who performed less well appeared to struggle with the underlying concepts and mathematical tools required to answer some of the questions. Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

There seemed to be no time constraints as almost all candidates were able to complete the paper.

Comments on specific questions

Question 1

(a)   Most candidates produced an acceptable table with correct headings. The majority of candidates gave the correct units of rate. Few candidates recorded the reaction time to the nearest second and/or recognised the accuracy to which a burette can be read. As burettes are calibrated at 0.10 cm^3, volumes should be recorded to 0.05 cm^3, i.e. should end in .#0 or .#5. The majority of candidates chose suitable volumes for all solutions in Experiments 3−5. Most also correctly calculated the rates of reaction, with the most common error being wrongly rounding the answer.

(b)   Most candidates labelled their graphs and chose scales that used the majority of the space available. Candidates should avoid choosing difficult scales e.g. one square = 0.45. This almost always produces errors when the points are plotted.

(c)   Most candidates stated that the rate of reaction went up with increases in concentration which was insufficient to gain credit. The better performing candidates recognised that to be directly proportional, not only was it necessary to state that the plot was a straight line but also that it went through the origin.

(d)   Most candidates drew the lines at the correct points on their graph.

(e)   Nearly all answers were based on reaction rates being in some way affected by surface area, with few stating that the solution would be less deep in the Petri dish and therefore more sulfur would be needed to obscure the printing on the insert when viewed from above.

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Question 2

(a) Most candidates produced an acceptable table with correct headings. A number of candidates omitted to record the changes in mass or temperature. In gravimetric exercises, all balance readings should be recorded to the same number of decimal places, generally 2 or 3: the syllabus specifies 2 decimal place balances are needed to obtain the required level of accuracy. Since the thermometers used could be read to $\pm 0.5°C$, the thermometer readings should be quoted to that degree of accuracy. Most candidates gained at least partial credit.

(b)(i) Most candidates were familiar with the use of energy = $mc\Delta T$. A very large number used the mass of solid rather than the 25.0 g that was the mass of solution.

(ii) In these calculations it was necessary to use the relative atomic masses as they are given in the Periodic Table and not those shortened to an integer. Most candidates gained partial credit and a significant number gained full credit for the calculations of ΔH.

(iii) This question was generally not well answered. Most candidates used a Hess's cycle method with only a few cancelling relevant equations to reach the desired reaction. Since the two numbers involved were available for all candidates it was necessary, for the award of marks, for some explanation or working to be clearly shown.

Question 3

Throughout this question, it was essential to use precise descriptions of changes and the significance of these changes. For example, it is not a precipitate when a solid is added to a solution – it must be two solutions being mixed or as a result of a gas being bubbled into a solution. Although there was evidence that candidates were using the Qualitative analysis notes, overall this was not well completed.

(a)(i) Nearly all candidates used aqueous sodium hydroxide and aqueous ammonia. Few of them made a solution of **FA 5** before looking for the formation of a precipitate. Though the use of aqueous barium ions to test for sulfate ions was correct, few candidates followed the instruction that the 'name or correct formula of the element or compound must be given'. This meant that adding $Ba^{2+}(aq)$ was not acceptable. In this test, it is the possible effect of adding a strong acid to the initial white precipitate and not, as suggested by many candidates, the effect of excess barium ions.

(ii) Some candidates gave the correct answers in the table, but these could not be justified by their observations in **(i)**.

(b)(i) Nearly all candidates gained at least partial credit. The instruction to record all observations was clear and this should have told candidates that a significant number of observations were possible.

(ii) In **Test 1**, the fizzing/effervescence was recorded by nearly all candidates. It should be noted that in this paper, and subsequent papers, the description of the limewater test must be the formation of a white precipitate. Terms such as cloudy/milky/milky white are no longer acceptable. In **Test 2**, the initial precipitate is blue or pale blue whilst the final solution must be described as dark or deep blue.

(iii) Both ions were given correctly by many candidates.

(iv) An acceptable equation was given by only the better performing candidates. The significance of it being ammonia that was added led most of the candidates who attempted the question to write an equation including NH_3.

CHEMISTRY

Paper 9701/32
Paper 3 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.
* Use the Periodic Table and qualitative analysis notes at the back of the paper.
* For qualitative work, present results clearly and use the correct terminology.

General comments

Candidates should use the space provided to prepare tables and record data. Candidates should present their data clearly and unambiguously. If corrections are required, the incorrect answer should be crossed out and the correct answer written next to it.

Most centres made up the solutions correctly according to the confidential instructions. Centres should note that the composition of solutions put before candidates do not always match the information in the paper; this is deliberate, and solutions should always be prepared using information in the confidential instructions.

Comments on specific questions

Question 1

This question was concerned with using mass loss on heating to determine the A_r of a Group II metal in a basic carbonate. Stronger candidates presented data clearly and in the correct place.

(a)   Stronger candidates could prepare a table for their results, and they understood that once heating of **FB 1** had started, it was no longer **FB 1** and should be referred to as 'the residue' or similar. Stronger candidates managed four correct weighings. Weaker candidates did not include space for the calculated residue mass, or they confused the residue mass with the mass loss on heating.

(b)(i)   Stronger candidates could construct a balanced symbol equation with correct state symbols. Weaker candidates had trouble constructing this equation using the information given in the question. The most common errors were not balancing correctly, omission of state symbols or incorrect state symbols.

(ii)   Stronger candidates were able to calculate the moles of carbon dioxide produced in their experiment. Weaker candidates confused residue mass for mass loss in **(a)**.

(iii)   Most candidates could calculate the M_r from their data. Weaker candidates used more than 4 significant figures.

(iv)   Candidates who calculated **(b)(iii)** correctly were also able to calculate the A_r correctly.

(c)   Stronger candidates were able to articulate the effect of spilling some residue through the calculations on the amount of carbon dioxide released and then on the calculated A_r. Weaker candidates did not attempt this question.

(d)   Stronger candidates understood that the reaction between acids and carbonates produces effervescence and so correctly concluded that addition of sulfuric acid would show if complete

decomposition had occurred. The strongest candidates spotted that the acid would also react with the metal oxide residue. These candidates needed to expand on their answer.

Question 2

This involved the titration of a standard solution made up by candidates to determine the identity of a Group I metal carbonate. Most candidates were comfortable with the titration. The stronger candidates completed the calculations to a high standard with the strongest candidates obtaining completely correct answers.

(a)   Most candidates completed the titration accurately demonstrated by correctly recording burette readings in correctly labelled tables.

(b)   Stronger candidates could generate a correct average titre from their data. Weaker candidates used the rough titre in their calculation, used titre data that was not concordant or used data with the incorrect number of decimal places.

(c) (i)   The strongest candidates gave all their answers to an appropriate number of significant figures. Weaker candidates gave answers to 1 or 5 significant figures.

(ii)   Most candidates could calculate the amount of HCl in their titre. The weakest candidates forgot to divide the average titre by 1000 to convert cm^3 into dm^3.

(iii)   The strongest candidates were able to construct the ionic equation with the correct state symbols. Weaker candidates attempted a full equation and gave incorrect state symbols, especially for the carbonate ion.

(iv)   The strongest candidates calculated the concentration of the carbonate in their standard solution. Weaker candidates forgot the factor of ten and/or the $1:2$ ratio in the balanced equation.

(v)   Stronger candidates answered this well using a variety of methods to get their answer. Weaker candidates needed to consider that the mass of solid was dissolved in $250\,cm^3$ of water not $1\,dm^3$.

(vi)   Most candidates who correctly answered **(c)(v)** correctly calculated the A_r of **X**.

(vii)   Most candidates who correctly answered **(c)(vi)** were able to choose a metal ion of close to that mass. Weaker candidates used a Group II metal or chose an element from the Periodic Table that had a mass closest to their answer, regardless of its chemistry.

It should be noted that the weakest candidates picked a metal (normally sodium) for **(c)(vii)** and then gave its mass in **(c)(vi)** and a contrived M_r in **(c)(v)**.

Question 3

The question focused on qualitative analysis of several unknown compounds. All tests were covered in the qualitative analysis notes with the exception of **(b)(iii)** and **(iv)**. All tests in **(b)** were to distinguish between two compounds and candidates were expected to choose one test only and conduct it. Many candidates attempted more than one test, even after having concluded the identity of the unknown.

(a) (i)   Most candidates selected $NaOH$ and NH_3 as their reagents to test for the cation and observed white precipitates which did not dissolve in excess and were able to clearly note their observations. Weaker candidates recorded precipitates dissolving or, when NH_3 was the reagent, not seeing a precipitate at all.

(ii)   Most candidates selected the correct reagents. Weaker candidates wrote the incorrect formula for barium chloride or identified the reagent as 'Ba^{2+}'. Candidates should be aware that testing the solubility of a barium salt precipitate using sulfuric acid will not work. Further testing with $KMnO_4$ was also seen.

(iii)   Candidates with at least one test correct in each of **(b)(i)** and **(b)(ii)** tended to get the correct formula, $MgSO_4$. Those who saw soluble precipitates in **(b)(i)** incorrectly put $ZnSO_4$, or if no precipitate with NH_3, $CaSO_4$.

(b) (i) Most candidates incorrectly tested with NaOH and Al foil however many also tested with KMnO$_4$ to correctly identify the nitrite.

(ii) Most candidates knew that there was no test in the notes for Na$^+$, so selected a reagent that would show the presence of Ag$^+$ with good results. Weaker candidates selected several reagents which contradicted a correct answer and some attempted to react the unknown with iodine rather than an iodide.

(iii) Stronger candidates selected the correct reagents. To observe the yellow precipitate candidates needed to leave the reaction for longer. Weaker candidates seemed unfamiliar with the iodoform test. Those who attempted it tended to forget the addition of a hydroxide was necessary.

(iv) Most candidates correctly identified ethanoic acid using a range of reagents or tests. Some candidates included gas tests which were unnecessary in the context of the question; where gases were tested, they were generally correct.

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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.
- Use the Periodic Table, data section and Qualitative analysis notes at the back of the paper.
- For qualitative work, present results clearly and use the correct terminology.

General comments

This practical paper contained questions using techniques familiar to most of the candidates. Some candidates appeared to have only limited practice in some of the techniques and in discussing their underlying chemistry. This led to a wide spread of marks.

Some candidates appeared to struggle with the underlying concepts and mathematical tools required to answer some of the questions. Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

There seemed to be no time constraints as almost all candidates were able to complete the paper.

Comments on specific questions

Question 1

A minority of candidates appeared not to have practised titrating solutions. The quality of the practical work was generally good. Some candidates found the latter parts of the calculation demanding.

(a) A majority of candidates gave burette readings for the rough titration; many only recorded the titre value. Candidates are required to read and act on the instructions in the method. Most candidates set out their tables of results correctly, though there were some accurate burette readings that had not been given to the required ##.#0 or ##.#5 cm^3. Once an accurate titre is $0.10\,cm^3$ or less away from any other accurate titre, there is no need to perform further titrations. Some candidates incorrectly carried out a third or fourth titration that was then more than $0.10\,cm^3$ from any of the others, so could not be credited. The level of accuracy was generally good. It is important that the Supervisor uses the same batch of chemicals as the candidates and that the best practical chemist carries out the task. It is not enough for Supervisors merely to write in a number for the titre without the burette readings to confirm their answer.

(b) Many candidates gained credit here. The most common errors were to select titres that had a spread of more than $0.20\,cm^3$ or to give the answer to one or three decimal places.

(c) (i) Almost all candidates were successful in this part.

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

(iii) A large majority of candidates calculated the M_r of $NH_2OH{\cdot}HCl$ correctly; fewer noted the amount pipetted into the conical flask so did not use the factor of 0.025.

(iv) Owing to an incorrect answer in **(c)(iii)**, many candidates found this part impossible and appeared to guess the 'correct' equation number. Better performing candidates showed logical working and an answer that corresponded to their results.

Question 2

Most candidates were able to carry out the practical task. More careful reading of some of the parts of the questions would have helped others. Candidates generally found the last part of the question challenging, which indicates that more time could be spent discussing errors and improvements in practical techniques.

(a) Most candidates selected suitable volumes of **FA 4** and water and kept the volume of **FA 3** as 10.0 cm^3. The candidates who had read through the question prior to starting the experiment were advantaged by selecting 25.0 cm^3 of **FA 4**. This value made the arithmetic in **(b)(ii)** easier. Some candidates did not give the times to the nearest second. A large majority of candidates gained at least one mark for accuracy.

(b)(i) There appeared to be several interpretations of the part involving concentrations and candidates were credited whichever of the three ways they decided to calculate these values. Some candidates lost credit for calculating the rates, rounding errors or inconsistent decimal places or significant figures.

(ii) Candidates with good mathematical skills performed well. Many candidates gained credit for comparing sets of data. This could be for comparing the ratio of concentrations with the ratio of rates or for calculating the value of k in rate = $k \times$ concentration (or rate = $k \times$ concentration^2) in at least two experiments. An explanation for their choice of response in Table 2.3 was also required and this was missing from most candidates.

(c) The most common errors in this part were to double the 0.5 cm^3 error when only one reading was taken or to use 50 cm^3 as the volume measured when the question specifies Experiment 2, where the volume of **FA 4** was 30.0 cm^3.

(d) Many answered along the lines of 'take more readings' without making it clear that these were separate experiments and not simply repeats of those already carried out. Some ignored the rubric and suggested changes to the apparatus or to the timing of the experiments. Credit was given to candidates who suggested plotting volume or concentration of **FA 4** against time, provided they went on to state the connection between half-life and the appropriate statement in **(b)(ii)**.

Question 3

It is important that candidates use the correct terminology when describing their observations. For example, adding a solid to a solution is not forming a precipitate. Precipitates are formed when two solutions are mixed, or a gas is bubbled through a solution and a solid appears. Greater use of the Qualitative analysis notes combined with a consideration of what the questions required would have enabled more candidates to perform better.

(a)(i) Few candidates gained full credit here. Many candidates noted the condensation formed near the mouth of the hard-glass test-tube. When instructed to heat an 'unknown', candidates should prepare litmus papers and limewater ready to test any gas formed once they start heating. It is important to note changes of state and any colour changes (or lack of them). Here, the solid was still white on cooling.

(ii) Many candidates noted that the solid dissolved, few stated the solution formed was colourless. Candidates should be taught the difference between colourless and clear. The latter applies to all solutions as well as to gases and to some solids and is synonymous with transparent.

(iii) Most candidates recorded correct observations.

(b)(i) Many candidates noted effervescence and either that the solid dissolved or (fewer) that the gas was tested with limewater. The instruction in the introduction to the Qualitative analysis section to test any gas formed in a reaction was ignored by many. Centres should advise candidates that stating limewater turns milky or cloudy white is not acceptable at this level and candidates should state that carbon dioxide forms a white precipitate when bubbled through limewater.

(ii) There were many suggestions for the identity of a cation in **FA 5**, almost all of them incorrect. Only a few candidates considered their results in **(b)(i)** and concluded that, as a carbonate gives carbon dioxide when reacted with an acid, one of the cations must be H^+.

(iii) Another instruction in the introduction to the Qualitative analysis section is to give the correct name or formula of any reagent selected for a test. Hence, those writing Ba^{2+} or $BaNO_3$ or $BaCl$ could not be credited. While the observation of the formation of a white precipitate was correct, fewer candidates went on to add a named acid to check its solubility. As the test is to distinguish between sulfate and sulfite, adding sulfuric acid is incorrect. Those testing the solution from **(b)(i)** with potassium manganate(VII) to distinguish between the two anions should have noted that the solution remained purple.

(iv) One of the anions identified had to be CO_3^{2-} and the other could be SO_4^{2-} or could be Cl^-/Br^- depending on the observations recorded in **(b)(iii)**. Many candidates answered this correctly.

(v) The most commonly seen correct ionic equations were those for $Ba^{2+}(aq) + SO_4^{2-}(aq)$, $Ag^+(aq) + Cl^-(aq)$ or $H^+(aq) + CO_3^{2-}(aq)$, though some candidates did not balance the latter. This was rarely awarded and many candidates appeared unaware of what was required.

(c) There were a few excellent responses to this question. Many candidates incorrectly added aluminium to the reaction mixture before any test for the NH_4^+ ion had been carried out. Few candidates made it clear that it was the gas they were testing with (damp red) litmus paper. Some candidates continued to test for an anion containing nitrogen when ammonia had been identified on heating with NaOH(aq) alone despite the introduction stating that only 'one of the two ions contains a nitrogen atom'. Many candidates went on to test with aqueous silver nitrate, which was not required in the question.

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Paper 9701/34
Paper 3 Advanced Practical Skills

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 to record data before commencing practical work.
*   Use the Periodic Table, data section and Qualitative analysis notes at the back of the paper.
*   For qualitative work, present results clearly and use the correct terminology.

General comments

This practical paper contained questions using techniques familiar to most of the candidates. Some candidates appeared to have only limited practice in some of the techniques and in discussing their underlying chemistry. This led to a wide spread of marks.

Some candidates appeared to struggle with the underlying concepts and mathematical tools required to answer some of the questions.

There seemed to be no time constraints as almost all candidates were able to complete the paper.

Comments on specific questions

Question 1

Most candidates were able to carry out the practical task to a good standard. The responses to calculation parts of this question were variable.

(a)   The vast majority of candidates recorded all their temperatures correctly. Thermometers are calibrated at $1\,°C$ so should be read to the nearest $.5\,°C$. Some candidates incorrectly recorded thermometer readings as $.00$ or $.50\,°C$, as integers or to $.1\,°C$. A large number of candidates gained at least 1 mark for accuracy, with many gaining full credit.

(b) (i)   Few candidates were awarded full credit for this question. The majority of the candidates correctly labelled the axes and used even scales. Some candidates started their y-axis scale at $0\,°C$, which meant the plotted points used too little of the available space. A few candidates omitted a temperature $2\,°C$ above the maximum thermometer reading which was required by the question. Points were generally plotted accurately and centred on vertical scale lines. Candidates should be encouraged to sharpen their pencils before plotting a graph so that one line in a '×' does not occupy over half a small square. Few candidates gained the final mark in this question, usually because a straight line was drawn for the rise in temperature when the plotted points clearly indicated a curve was required.

(ii)   Many candidates correctly read the volume at the intersection of their two lines. Candidates were not awarded credit if there was no intersection, they gave an integer value for the volume or they misread the x-axis scale.

(c) (i) A variety of errors were seen here. Few candidates appreciated that the mass used in the calculation is calculated by the addition of 25.0 to their answer for **(b)(ii)**. Some candidates incorrectly used $4.2 \, J \, g^{-1} \, K^{-1}$ in place of $4.18 \, J \, g^{-1} \, K^{-1}$ as given in the Qualitative analysis notes. Some candidates used the maximum temperature rather than the maximum temperature change and a very small number added 273 to the value they believed to be the temperature change.

(ii) This question was very well answered.

(iii) Most candidates were able to use their answers to **(c)(i)** and **(c)(ii)** to calculate the enthalpy change and gave the correct sign. A few candidates reported their answer to more than 4 significant figures which is not appropriate.

(iv) Many candidates showed their working and calculated the answer for this question. Some candidates omitted the use of the concentration of **FB 2** (the 'information given on page 2').

(v) Candidates needed to show use of their answer for **(c)(iv)** and either subtract 73 or use the correct formula masses of the suggested compounds. They needed to show some working and were not credited for seeming to guess the identity of **FB 2.**

(vi) Few candidates calculated the percentage error. Some incorrectly used 0.5 as the numerator in a percentage calculation. Others found the error using atomic masses rather than molecular masses or incorrectly used their answer to **(c)(iv)** as the denominator rather than the M_r for the acid identified in **(c)(v)**.

Question 2

As stated in the current syllabus, spirit burners in place of Bunsen burners are not suitable as the flame temperature is too low to drive off sufficient water or carbon dioxide from many of the compounds that are used in these exercises. Centres are also reminded that the syllabus requirement is for a balance which reads to at least two decimal places. A one decimal place balance usually disadvantages candidates when carrying out this type of practical question.

(a) Almost all candidates recorded the three required weighings to a consistent number of decimal places. Candidates needed to record them in the **Results** section to gain credit. Candidates should always follow the method given and not carry out additional steps, e.g. additional heating and weighing. The main error in the headings was to refer to the mass of residue as '**FA 3** after heating'. The residue should be almost entirely metal oxide rather than metal carbonate. Some confused the mass of **FA 3** used with the mass of residue and more confused the mass loss with the mass of residue. There was generally good agreement in the ratio of mass of **FA 3**: mass of residue. Most gained at least 1 mark for accuracy.

(b) (i) The majority of candidates calculated the amount of carbon dioxide lost on heating.

(ii) The majority of candidates correctly calculated the M_r of **FB 3**. A number stated the answer to more than 4 significant figures which is not appropriate. A few candidates carried out an additional step and gave the A_r of **M** as their answer rather than the M_r of the compound.

(iii) A number of candidates made no attempt at this question as their previous answer was either too large or too small to be sensible. Those that had a sensible value for **(b)(ii)** usually calculated the A_r of **M** without difficulty. Some went on to incorrectly select the element with the closest A_r to the one calculated. Few candidates realised that **M** was likely to be a Group 2 element. Zinc, tin and lead were acceptable alternatives.

(c) Very few candidates answered this correctly.

(d) A number of candidates gave just 'limewater' as the test to determine whether all the metal carbonate had decomposed. Limewater may be used to test gas given off after the addition of acid or after further heating of the residue but cannot be used alone. Centres should advise candidates that stating limewater turns milky or cloudy white is not acceptable at this level and candidates should state that carbon dioxide forms a white precipitate when bubbled through limewater.

Question 3

It is important that candidates use the correct terminology when describing their observations. For example, adding a solid to a solution is not forming a precipitate. Precipitates are formed when two solutions are mixed, or a gas is bubbled through a solution and a solid appears. Greater use of the Qualitative analysis notes combined with a consideration of what the questions required would have enabled more candidates to perform well.

(a) (i) The full range of marks was seen for this question. A small number of candidates incorrectly added all three reagents to the same test-tube. For **Test 1**, candidates are reminded that when acidified potassium manganate(VII) is used, the key observation is whether it loses its colour or not. When mixed with **FB 4**, 'solution turns purple' was not accepted as a correct observation because no change or reaction has taken place; the purple solution remains purple. Some candidates were incorrectly using the term 'decolourise' to suggest a change in colour, e.g. from purple to brown, rather than the production of a colourless sample. For **Test 3**, some candidates did not report effervescence with magnesium for any of the acids and very few candidates correctly described the test for hydrogen gas. A small number of candidates noted whether the magnesium either remained or had disappeared after 3 minutes.

(ii) A number of candidates made no reference to their own observations. Some candidates carried out additional tests, such as using barium nitrate to identify sulfuric acid, when the instruction was that 'No additional tests should be attempted' and therefore lost credit.

(b) (i) The question states that **FB 2** was heated with **excess** aqueous sodium hydroxide. The relevance of this was missed by almost all candidates, so very few added acid before using silver nitrate. Whilst most candidates used silver nitrate solution, many gave unclear descriptions of the resultant precipitate, e.g. 'cream-white'. Candidates needed to add aqueous ammonia to confirm their choice of identity. Most candidates did conclude the correct halogen; many incorrectly wrote the name or symbol for the halide rather than the halogen, which meant credit was not awarded.

(ii) This question was generally not well answered, with most candidates not understanding the reaction and suggesting an organic product which still contained the halogen. A very small number of candidates gave a fully correct equation.

CHEMISTRY

Paper 9701/35
Paper 3 Advanced Practical Skills

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.
- Use the Periodic Table, data section and Qualitative analysis notes at the back of the paper.
- For qualitative work, present results clearly and use the correct terminology.

General comments

This practical paper contained questions using techniques familiar to most of the candidates. Some candidates appeared to have limited practice both in the techniques and in discussing their underlying chemistry. This led to a wide spread of marks.

Some candidates appeared to struggle with the underlying concepts and mathematical tools required to answer some of the questions. Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

There seemed to be no time constraints as almost all candidates were able to complete the paper. Some candidates left many questions unanswered.

Comments on specific questions

Question 1

Some candidates appeared not to have had the opportunity to discuss issues arising from a gas collection procedure. The quality of the practical work was generally good. Some candidates found the latter parts of the question demanding.

(a) The majority of candidates were successful in gaining at least 1 mark for accuracy. Candidates needed to give the balance readings to 2 or 3 decimal places and an integer value for the volume of gas collected to gain credit. Candidates should be aware that calibrated apparatus may be read to half a division, hence volumes measured using a $250\,cm^3$ measuring cylinder should be to the nearest cm^3. The inclusion of ###.0 implies the volume has been read to 0.1 or $0.5\,cm^3$ accuracy, which is not acceptable.

(b)(i) Most candidates calculated the amount of hydrogen collected correctly.

(ii) Some candidates incorrectly used their mass of magnesium from **(a)** and its A_r to calculate the amount of Mg reacting rather than their answer to **b(i)**. Those who followed the instructions given generally performed well.

(c) Some candidates correctly suggested that the rate would be greater or that there would be greater corrosion both owing to the increased surface area of the Mg. Few went on to link this with the procedure they had just carried out and that there would be more gas loss before the bung could be inserted in the reaction flask.

(d)(i) A sizeable number of candidates answered this correctly. Some attempted to answer this part while stating hydrogen would be given off instead of carbon dioxide as given in the question.

(ii) Some candidates were able to link a small loss in mass with a lack of precision of the balance. Few candidates noted the difference in mass of H_2 compared to CO_2.

(iii) Better performing candidates were able to write a balanced ionic equation with the correct state symbols.

Question 2

The technique employed in a thermometric experiment and its subsequent calculations appeared more familiar to candidates and some good performances were seen. Some candidates lacked the graphical skills to perform well.

(a) A large majority of candidates gained at least one mark for accuracy with many gaining both. The thermometers stipulated in the syllabus are calibrated at $1\,°C$ thus should be read to ##.0 or ##.5 $°C$. This was not given by many candidates.

(b)(i) Most candidates labelled the correct axes. Fewer selected a suitable scale which incorporated the $15\,°C$ above the highest temperature recorded in **(a)**. Almost all candidates selected linear scales so were able to plot the points correctly. It is important that plotting is carried out with care, as some of the points that should have been on a line were not and some of the pencil markings were too large for the required precision.

(ii) Candidates should be aware that lines of best fit may be straight or a smooth curve. There were a number of scripts where a straight line was drawn and a curve would have been appropriate, and so could not be credited. As the thermometers are read to ##.5$°C$ the temperature values at the intersect and at 2 minutes should have been read to at least ##.5$°C$ and ΔT calculated to 1 decimal place; many answers were given as integers.

(c)(i) Most candidates answering this part used energy change = mc ΔT. Some used the mass of Mg given in **(a)** instead of $25.0\,g$ that was the mass of the solution. Some gave the answer to an inappropriately large number of significant figures. The significant figures given in an answer should reflect the precision of the masses or concentrations of the reactants as well as the precision of the apparatus used.

(ii) Many of those who were successful in **(c)(i)** were also successful in this part. Almost all of those attempting this part calculated the amount of Mg added. The errors in the final answer were generally an incorrect sign or not converting J to kJ.

(iii) Some candidates appeared confused as they calculated the percentage **impurity** in the Mg. Candidates should be encouraged to show their working. Those who inverted the expected expression of $(\textbf{(c)(ii)} \div -452) \times 100$ were not credited.

Question 3

It was particularly important for candidates to read through and act on the initial instructions given in the Qualitative analysis notes. Precision of terminology is essential for those wishing to perform well. Use of the Qualitative analysis notes would also have been of benefit. Those who were practised in this type of question or who used the information given performed well.

(a) There were two ways to approach this task. The most commonly seen approach was to add acid to **FA 5** and look for effervescence. The second approach was to heat the solid and test any gas evolved. The acid had to be named (as stated in the instructions) and, as $CO_2(g)$ was a possible product, the apparatus for testing the gas with limewater should have been to hand. As acid had to be added to **FA 5** before any test for $Mg^{2+}(aq)$ could be carried out, the solution of the metal ion would have been acidic. Therefore, it was important to add sufficient $NaOH(aq)$ or $NH_3(aq)$ to neutralise the acid before any cation could react.

(b)(i) Candidates were generally successful in this part. Some would have benefited from using the colours for precipitates given in the Qualitative analysis notes. There were instances in **Test 1** where candidates claimed a grey-green precipitate (implying precipitate with Cr^{3+}) followed by the precipitate turning brown (implying Fe^{2+} with aerial oxidation). There was more evidence for an iron ion at the end of **Test 2** so candidates should have been able to amend their initial description of the colour of the precipitate in **Test 1**. When hydrogen peroxide is used in a test, one of the possible outcomes is the production of oxygen. Candidates reading through the tasks before starting the practical could prepare by having a wooden splint ready to use. **Tests 3** and **4** were the usual tests for anions. Care is needed in describing the precipitate with $AgNO_3$(aq), especially as there were interfering reactions on adding NH_3(aq), so the solubility of the precipitate was impossible to gauge. Most candidates were successful in **Test 4**. Those unsure of the initial precipitate colour in **Test 3** were given more evidence in **Test 5**; the purple colour of the reagent changed to brown or formed some black solid showing iodine had been formed.

(ii) Most candidates answering this part were able to gain at least one of the marks and a minority gained full credit.

(c)(i) Many correct answers were given. Some candidates simply repeated their observations for **(b)(i) Test 5**.

(ii) Better performing candidates were successful in balancing the half equation. Some were able to give the correct number of water molecules formed. Some candidates used an incorrect number of electrons needed to balance the equation.

CHEMISTRY

Key messages

- Many candidates used general wordings and imprecise terminology. Those candidates who had learned the exact wordings necessary gained more marks.
- Candidates must ensure their handwriting is legible as poor handwriting on some scripts can make it impossible to distinguish, for example, 4s from 7s or 9s, or 3s from 2s or 5s.
- Some candidates chose to cross out an answer and write another answer on top of the crossings out. This should be avoided as it can make answers unreadable.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Answers to calculations should be given to a minimum of two significant figures with three significant figures preferred. In a calculation that involves two or more stages, the full number should be left on the calculator after each stage and then the final answer should be rounded to three significant figures.
- 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.

General comments

Some questions examined syllabus content by setting problems in unfamiliar contexts. Some candidates presented very good scripts and a significant number of excellent ones were seen. A few candidates had difficulty with these types of questions.

Candidates must ensure that the correct following of convention and care is taken when writing the formulae of substances. For example, in **Question 1(a)**, the nitrate ion should have been written as NO_3^-, not NO_3^{2-}, NO_2^-, or NO^-, and in **Question 1(b)**, the formula of copper nitrate should have been shown as $Cu(NO_3)_2$, not $CU(NO_3)_2$ or $cu(no_3)_2$.

The word 'reagent' should be used sparingly or not at all when submitting answers on a written exam paper. On some scripts it was used as a coverall term for all or some of the 'reactants', 'products', 'catalysts' and 'conditions'. In no cases did this help candidates gain credit.

The ability to perform calculations correctly is an integral part of chemistry. Candidates need to ensure they round a number correctly. It is best if such rounding is done at the end of a calculation, rather than after each individual step.

Comments on specific questions

Question 1

(a)   This question was answered well.

(b)   This question was answered well.

(c)   The majority of candidates achieved some or full marks. $(Cu(NH_3)_6)^{2+}$ was a common error for the formula of **C**.

(d)(i) Stronger candidates had learnt the standard definition of a polydentate ligand.

(ii) A significant number of candidates did not answer this question.

(iii) Some candidates submitted an answer that could mean the denticity of the ligand, e.g. 'the number of bonds between a ligand and a metal ion', rather than the coordination number of the metal ion.

(iv) 'Redox' was a common wrong answer.

(v) This was usually answered correctly. Some candidates referred to 'the position of equilibrium' lying to the right. Since there was no equation for a reversible reaction on the question paper this could not be given credit.

(e) Candidates found this to be a difficult calculation. Few candidates understood that each formula unit of $Cr_2(SO_4)_3$ contains **two** Cr^{3+} ions. This error led to an M_r value of 304 and the impossible answer that n=−5. Candidates who performed better tended to annotate their working out and identify the purpose of each step of their calculation.

(f) Candidates who began their answer by thinking about the d-orbital splitting usually went on to perform well. Some ambiguous answers were seen in which the exact meaning of the candidate's reference to d-orbital splitting was unclear. Stronger candidates gave answers that included 'the two complexes have different ΔE' since ΔE is conventionally used for the size of the energy gap between split d-orbitals.

Question 2

(a) This was usually answered correctly.

(b) Few candidates understood the meaning of the term 'geometry'. 'Tetrahedral' was a commonly seen wrong answer.

(c) This was found to be a difficult question. The three nitrogen atoms in the complex can be 'meridial', where one N–Cr–N bond angle is 180°, or 'facial', where all N–Cr–N bond angles are 90°. The securest way to generate the four isomers is to draw one meridial isomer and its mirror image, and one facial isomer and its mirror image.

(d)(i) This was found to be difficult by many candidates.

(ii) This was answered correctly by the majority of candidates.

(iii) Many candidates drew unsaturated molecules, molecules that did not fit the given formula, or molecules without a basic amine group and so could not achieve the marks.

Question 3

(a)(i) Many candidates stated, 'the power of the concentration of a reactant'. Weaker candidates omitted 'in the rate equation'.

(ii) Most candidates completed the table correctly.

(iii) Both graphs start at (0, 0), and although the [I⁻] graph approaches vertical it does not quite reach verticality and it does not curve back towards the left-hand axis.

(iv) This calculation required some care and generally it was well handled. Candidates who chose to give the units as $mol^{-4} \, dm^{12} \, s^{-1}$ had to remember to calculate k in the same units. The question was more straightforward for candidates who left the rate in $mol \, dm^{-3} \, min^{-1}$ and so gave the units of k as $mol^{-4} \, dm^{12} \, min^{-1}$.

(v) This calculation required some care and generally it was well handled.

(vi) This was found to be very difficult. Some candidates realised that the ratio of [H⁺] concentrations is 10:1 but did not square this to get a final answer of 100.

(b)   Candidates found this to be a difficult question. Few candidates ensured two ions were involved in each step. Other common errors were:
- introducing species that are not involved in the reaction
- writing half-equations instead of equations
- writing equations that were not balanced for substances
- writing equations that were not balanced for charge.

Question 4

(a)   Candidates found this to be difficult. Some candidates produced some good answers. It was very important for candidates to take careful note of the sentence, 'Explain how orbital overlap leads to the formation of σ and π bonds in benzene'; this was an indication of the question requirements.

(b)(i)   This was answered well. A small number of candidates incorrectly gave **X** as nitrobenzene and **Y** as 4-isopropylnitrobenzene. This will not work, since the nitro group is 3, 5 - directing the alkyl group will substitute onto carbon atom 3, not carbon atom 4. It should also be noted that Sn is a reactant, not a catalyst, in the reduction of nitrobenzene to phenylamine.

    (ii)   Most candidates achieved marks for this question. Some candidates incorrectly used $C_2H_5CH_2Cl$ in place of $CH_3CHClCH_3$ or did not appreciate the acids used for other steps must be concentrated.

(c)   This discriminated well.

(d)   The number of peaks observed in the carbon-13 NMR spectrum of **W** was found to be much more difficult than the number for **Z**. 'Five' was a commonly seen incorrect answer for **W**.

Question 5

(a)(i)   Most candidates knew platinum is involved. Recalling palladium and rhodium proved more difficult.

    (ii)   This was usually answered correctly.

(b)(i)   Better performing candidates stated, 'The number of possible arrangements of particles and energy in a system'.

    (ii)   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 working. Candidates who were unable to calculate the correct answer were much more likely to gain partial credit if they wrote down their calculated values for ΔH and ΔS.

(c)   Very few candidates achieved the mark. Candidates found that using three chemical equations to generate one overall equation difficult.

(d)   It is essential candidates use the information in the question. Several structures were possible based on this information. Structures that did not fit the given molecular formula or did not have alternating carbon and nitrogen atoms in the ring could not be given credit.

(e)(i)   This was usually correct. The most common error seen was the omission of the square brackets in $-\log[H^+]$.

    (ii)   The majority of candidates achieved the answer pH = 2.31. Some candidates missed the instruction to give their answer to three significant figures.

    (iii)   This discriminated well.

Question 6

(a) (i)   The functional groups were usually correctly named.

(ii)   Many well drawn 3D diagrams were seen.

(b) (i)   Candidates found this difficult. Many candidates assumed that the anion contained in the 'excess of hot aqueous acid' was a reactant and so they tried to balance an equation that included Cl^- or SO_4^{2-}. The acid is a catalyst, the second reactant is water, and the reaction is hydrolysis.

(ii)   This discriminated well.

(c) (i)   The repeat unit was usually correct.

(ii)   Most candidates gave a correct amide link. Care was necessary to ensure that all the remainder of the diagram was correct.

(iii)   Some good answers were seen.

Question 7

(a)   Many candidates gave a correct order: diethylamine – ethylamine – ethanamide. Stronger candidates gave some good explanations. Weaker candidates found the explanation challenging. It should be noted that:
- The basicity of these compounds is due to the ability of the lone pair of electrons on the nitrogen atom to accept a proton.
- 'Attract a proton' is **not** equivalent to 'accept a proton'. 'Accept a proton' or 'form a coordinate bond to a proton' are the correct terms to use when describing the basicity of a compound such as the three compounds in this question.
- The lack of basicity of an amide is due to the lone pair of electrons on the nitrogen atom being delocalised into the C=O group.

(b) (i)   This was answered well. Many candidates knew that a buffer solution resists changes in pH and that it does not maintain constant pH.

(ii)   Many candidates incorrectly used species such as $H_2NCH(CH_3)COO^-$ or $H_3N^+CH(CH_3)COOH$ on the left of their equations. These species will be in comparatively low concentrations in an aqueous solution of alanine.

(c) (i)   The most common errors included the carboxylic acid groups being shown as COOH.

(ii)   Many tripeptides and sections of polypeptide chain were seen. Since a dipeptide was asked for, the terminal groups should have been $-NH_2$ and $-COOH$. If the $-NH_2$ group is shown on the left-hand end it should **not** be shown as $_2HN-$; NH_2- and H_2N- are both acceptable.

(d)   This was generally answered well. The most common error was to state that glu and ala-glu go towards the negative electrode.

(e) (i)   Many variant spellings were seen in the 'splitting pattern' column, including the incorrect 'duplet' and 'quadret' which were not awarded credit.

(ii)   Many candidates described the difference in such an NMR spectrum when D_2O is added, which was not what the question asked. Other candidates wrongly stated that H↔D exchange happens when $CDCl_3$ is added.

Question 8

(a)   The majority of candidates placed their ticks correctly for lattice energy and enthalpy of solution. Candidates found enthalpy of hydration more difficult.

(b)   Some good answers were seen.

(c) (i)   It is essential in a calculation for candidates to show their working.

   (ii)   Many candidates did not appreciate that their calculation initially gave a value for the $\Delta H^{\ominus}_{hyd}$ of **two** moles of Br^- ions.

   (iii)   A comparison of ionic radii was usually correct. The comparison of the attractive forces between the two ions and water molecules was awarded much less often.

CHEMISTRY

**Paper 9701/42
A Level Structured Questions**

Key messages

- Candidates must ensure their handwriting is clear to read. Handwriting that is too small often becomes illegible.
- 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 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. Many candidates were able to work through to the end of the paper, suggesting they had sufficient time.

Comments on specific questions

Question 1

(a) (i) Candidates generally found this question difficult. Some candidates did not attempt this question and many used incorrect curly arrows, for example ending at the C atom or breaking the C=O bond. Candidates were expected to add two curly arrows to form CO_2 and O^{2-}.
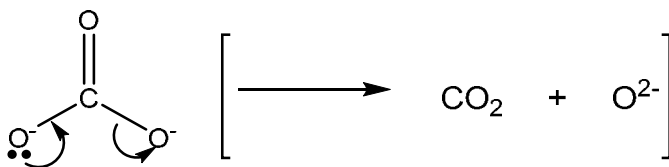
(ii) Most candidates had prepared well for this question. Many gave a correct statement regarding increasing stability and increasing cation radius down Group 2. Decreasing polarisation of the carbonate anion was less frequently seen. Some candidates incorrectly suggested there was polarisation of the cation or that polarisation was caused by the anion.

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

(ii) Candidates generally found this question challenging. Few candidates gave an answer in terms of the rubric. Some candidates gave vague answers without reference to either oxides or carbonates or the relevant sizes of the anions.

(c) (i) This question was generally well answered. A common error was cancellable H_2O or H^+ being included on both sides of the equation.

(ii) Candidates performed well on this question. Common errors included 6.52 (no ×10), 10.4 (2/5 ratio used), 26.1 (no 5/2 used) and 49.1 (M_r of 119.1 used).

(d) This was generally well answered. Common errors were octahedral and square planar.
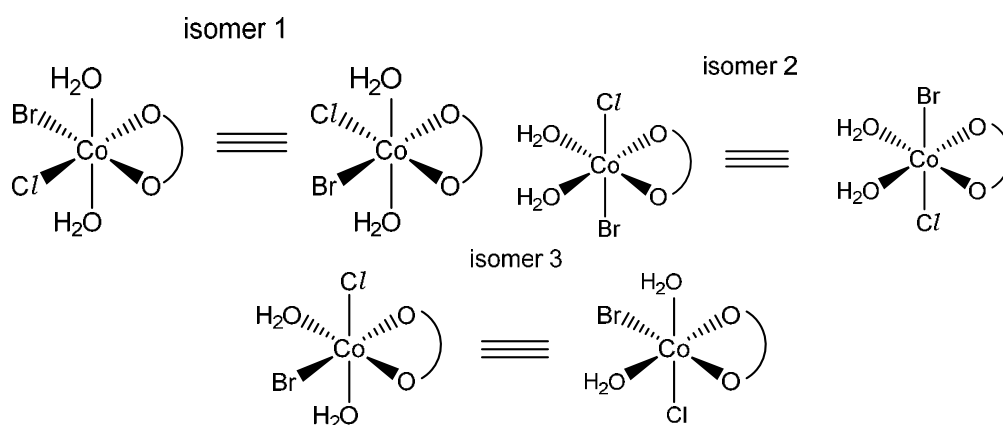
Question 2

(a) Many candidates were able to give two typical chemical properties of transition elements.

(b)(i) Most candidates gave a correct definition for a complex ion.

(ii) Some excellent answers were seen. The formulae resulted in the most errors such as $(Co(NH_3)_4(H_2O)_2)^{2+}$ and $(Co(OH)_6)^{4-}$. Other errors included yellow solution for $(Co(NH_3)_6)^{2+}$ and $(CoCl_4)^{2-}$. The type of reaction was well known.

(c)(i) This was generally answered well. Some candidates omitted 'metal' with metal atom/ion and so could not be awarded the mark.

(ii) Candidates performed well on this question. Common errors were giving the two structures of the same isomer as shown.

(iii) This was generally answered well.

Question 3

(a) This was generally answered well. A common error was suggesting that the enthalpy change of formation is always negative.

(b) This was generally answered well. Common errors included:
- one mole of gaseous ions are formed
- omitting 'one mole' with 'gaseous atoms'
- from one mole of element in their standard state.

(c) Candidates performed well on this question. Better performing candidates showed their working as required by the question.

(d) Many candidates were able to identify the trend and that O^{2-} has the smallest ionic radii/largest charge density. Some candidates did not clearly state that this would lead to greater attraction between the ions in Ag_2O.

(e)(i) This was generally answered well.

(ii) This was generally answered well. The most common error was 1.55×10^{-5}.

(f) Many candidates found this difficult. Most recognised that feasibility increases as temperature increases. Few candidates provided a suitable explanation in terms of ΔS ($T\Delta S$ becomes more positive) and/or ΔG becomes more negative.

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Question 4

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

(ii) Many good answers were seen. Most candidates were able to deduce the order for Fe^{3+}. Some candidates omitted a sufficient explanation using the data in Table 4.1.

(iii) This was generally well answered.

(iv) This was generally well answered.

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

(b) (i) Most candidates were able to identify step 1 as the rate determining step. Few candidates gave a suitable explanation in terms of H_2O_2 and I^- or the lack of H^+ in this step.

(ii) Many candidates correctly identified step 1 or 3. Few candidates gave a correct explanation in terms of oxidation numbers. Common errors included an incomplete explanation (only quoting the oxidation or reduction instead of both), or use of incorrect oxidation numbers, for example step 1 change in H from +2 to +1.

(iii) HIO as an oxidising agent for I^- was more common than as an intermediate. The most common error was HIO is acting as a catalyst.
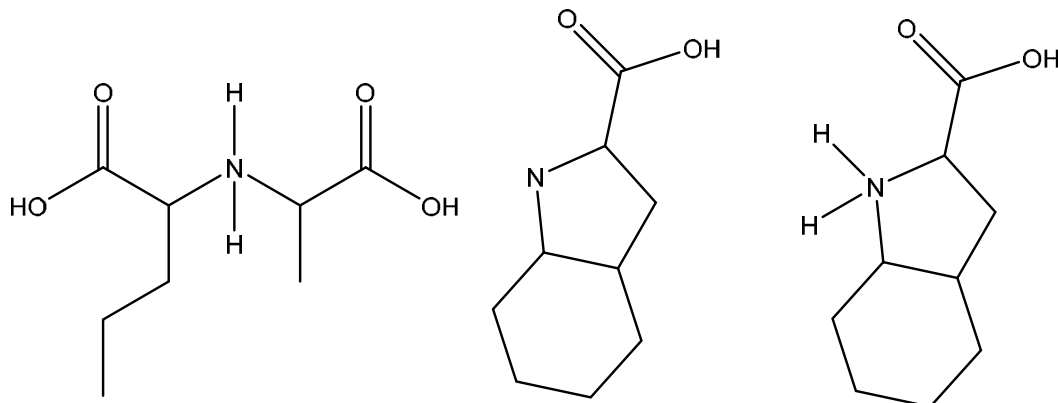
Question 5

(a) (i) This question was generally well answered. The question asked for the structure of the organic products. Some candidates incorrectly gave HBr as a product for reaction 3. Another common error was $C_6H_5CH_2Cl$ for reaction 2.

(ii) Most candidates answered this question well. Reaction 1 was normally correct as reduction or hydrogenation. A common error for reaction 2 was electrophilic substitution.

(b) This was not well known and proved difficult for candidates.

(c) (i) Those who had learned the electrophilic substitution mechanism found this to be accessible. Common errors included:
- the curly arrow in step 1 not starting inside the hexagon ring and going to the sulfur
- an incorrect structure of the intermediate – the partly delocalised ring should not include the sp^3 carbon, positive charge should not be on the sp^3 carbon, the sulfur and hydrogen atom in SOBr should have no charge
- the curly arrow in the intermediate starting on the H not on the C-H bond
- HBr being formed instead of H^+ ion at the end of the mechanism.

(ii) Many candidates gave the correct structure.

(d) (i) This was generally answered well. Common errors included starting with an incorrect formula of ethanoic acid, forming CH_3COOBr or H_2O as a product.

(ii) Many candidates found this challenging. Answers were often not sufficiently detailed. Common errors included:
- stating acyl chlorides were the easiest to hydrolyse
- few noted that the larger atomic radius of bromine would result in a weaker C-X
- omitting an explanation in terms of relative bond strength.

Question 6

(a) (i) Many candidates gave the correct number of chiral carbon atoms.

(ii) This proved difficult for candidates. Often answers were too vague, such as higher yield for a benefit and expensive for a disadvantage, which gained no credit.

(b) (i) This was generally answered well. Common errors were carbonyl and arene.

(ii) This question discriminated well. Full credit was given for neutral species; some candidates noticed that the amine groups are protonated under acidic conditions. Ethanol was normally correct, although the hydrolysis of the amide was found to be more difficult. The bonding with the N in the hydrolysed products caused some difficulties (number of Hs attached and charge on N). Some common errors seen are shown.

Question 7

(a) Candidates performed well on this question. Most candidates recognised that the lone pair on the O of OH 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 O was normally absent or in terms of increased charge density.

(b) Most candidates were able to identify iodobenzene. Few candidates gave a suitable explanation in terms of electronegativity.

(c) (i) Many candidates found this question difficult. The most common error was forming H^+ instead of H_2.

(ii) This was generally answered well.

(iii) This proved difficult for candidates, although some excellent answers were seen. The most common errors were:
- for reaction 1: use of concentrated HNO_3 or inclusion of H_2SO_4
- for reaction 2: omission of the benzene diazonium salt.

Question 8

(a) Most candidates found this question difficult. Few candidates were able to give both points why chlorobenzene does not undergo hydrolysis.

(b) (i) Many candidates found this challenging. Candidates had to use the name of the parent carboxylic acid (3-chloropropanoic acid) and parent alcohol (ethanol) to deduce the name of the ester (ethyl 3-chloropropanoate).

(ii) Many candidates found this challenging. The structures of **X** (ethanol) and **Z** (ethyl 4-aminobutanoate) were normally correct. The correct structures of **W** and **Y** was less common. The most common error was giving a partially hydrolysed product for **W** and **Y**.

Other errors included sodium ethoxide (instead of ethanol) and 3-chloropropanoic acid (instead of sodium 3-chloropropanoate).

(iii) This was answered well. The most common errors were:
- for step 1: use of HCN or omission of ethanol as the solvent
- for step 2: use of $NaBH_4$ or use of concentrated HNO_3 and H_2SO_4.

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

(ii) Most candidates answered this question well. Common errors included:
- identifying the splitting pattern at δ 3.9 as a 'quartet'. No credit was given for quatrat/quadlet/quardret
- the peak areas at δ 1.2 and 3.9 were sometimes reversed.

(iii) This was answered correctly by most candidates.

Question 9

(a) A significant number of candidates referred to the standard hydrogen electrode and therefore gave the definition for standard electrode potential, not standard cell potential.

(b) Many candidates gave a good answer. Some excellent clear, labelled diagrams were seen. Common errors included:
- omitting Pt electrode labels,
- labelling the Fe^{3+}/Fe^{2+} electrode as Fe
- labelling the electrolyte as Cl_2/Cl^- in the other half-cell.

(c) This discriminated well. Common errors included –56.9, 114 and –113870.

(d) (i) This was answered well, and many could use the Nernst equation correctly. The most common error was 0.72.

(ii) This discriminated well. Those that showed their working were often able to gain credit.

CHEMISTRY

Key messages

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(b)   This question was answered well.

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(ii) Most candidates completed the table correctly.

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(vi) This was found to be very difficult. Some candidates realised that the ratio of [H⁺] concentrations is 10:1 but did not square this to get a final answer of 100.

(b)   Candidates found this to be a difficult question. Few candidates ensured two ions were involved in each step. Other common errors were:
- introducing species that are not involved in the reaction
- writing half-equations instead of equations
- writing equations that were not balanced for substances
- writing equations that were not balanced for charge.

Question 4

(a)   Candidates found this to be difficult. Some candidates produced some good answers. It was very important for candidates to take careful note of the sentence, 'Explain how orbital overlap leads to the formation of σ and π bonds in benzene'; this was an indication of the question requirements.

(b)(i)   This was answered well. A small number of candidates incorrectly gave **X** as nitrobenzene and **Y** as 4-isopropylnitrobenzene. This will not work, since the nitro group is 3, 5 - directing the alkyl group will substitute onto carbon atom 3, not carbon atom 4. It should also be noted that Sn is a reactant, not a catalyst, in the reduction of nitrobenzene to phenylamine.

(ii)   Most candidates achieved marks for this question. Some candidates incorrectly used $C_2H_5CH_2Cl$ in place of $CH_3CHClCH_3$ or did not appreciate the acids used for other steps must be concentrated.

(c)   This discriminated well.

(d)   The number of peaks observed in the carbon-13 NMR spectrum of **W** was found to be much more difficult than the number for **Z**. 'Five' was a commonly seen incorrect answer for **W**.

Question 5

(a)(i)   Most candidates knew platinum is involved. Recalling palladium and rhodium proved more difficult.

(ii)   This was usually answered correctly.

(b)(i)   Better performing candidates stated, 'The number of possible arrangements of particles and energy in a system'.

(ii)   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 working. Candidates who were unable to calculate the correct answer were much more likely to gain partial credit if they wrote down their calculated values for ΔH and ΔS.

(c)   Very few candidates achieved the mark. Candidates found that using three chemical equations to generate one overall equation difficult.

(d)   It is essential candidates use the information in the question. Several structures were possible based on this information. Structures that did not fit the given molecular formula or did not have alternating carbon and nitrogen atoms in the ring could not be given credit.

(e)(i)   This was usually correct. The most common error seen was the omission of the square brackets in $-\log[H^+]$.

(ii)   The majority of candidates achieved the answer pH = 2.31. Some candidates missed the instruction to give their answer to three significant figures.

(iii)   This discriminated well.

Question 6

(a) (i) The functional groups were usually correctly named.

(ii) Many well drawn 3D diagrams were seen.

(b) (i) Candidates found this difficult. Many candidates assumed that the anion contained in the 'excess of hot aqueous acid' was a reactant and so they tried to balance an equation that included Cl^- or SO_4^{2-}. The acid is a catalyst, the second reactant is water, and the reaction is hydrolysis.

(ii) This discriminated well.

(c) (i) The repeat unit was usually correct.

(ii) Most candidates gave a correct amide link. Care was necessary to ensure that all the remainder of the diagram was correct.

(iii) Some good answers were seen.

Question 7

(a) Many candidates gave a correct order: diethylamine – ethylamine – ethanamide. Stronger candidates gave some good explanations. Weaker candidates found the explanation challenging. It should be noted that:
- The basicity of these compounds is due to the ability of the lone pair of electrons on the nitrogen atom to accept a proton.
- 'Attract a proton' is **not** equivalent to 'accept a proton'. 'Accept a proton' or 'form a coordinate bond to a proton' are the correct terms to use when describing the basicity of a compound such as the three compounds in this question.
- The lack of basicity of an amide is due to the lone pair of electrons on the nitrogen atom being delocalised into the C=O group.

(b) (i) This was answered well. Many candidates knew that a buffer solution resists changes in pH and that it does not maintain constant pH.

(ii) Many candidates incorrectly used species such as $H_2NCH(CH_3)COO^-$ or $H_3N^+CH(CH_3)COOH$ on the left of their equations. These species will be in comparatively low concentrations in an aqueous solution of alanine.

(c) (i) The most common errors included the carboxylic acid groups being shown as COOH.

(ii) Many tripeptides and sections of polypeptide chain were seen. Since a dipeptide was asked for, the terminal groups should have been $-NH_2$ and $-COOH$. If the $-NH_2$ group is shown on the left-hand end it should **not** be shown as $_2HN-$; NH_2- and H_2N- are both acceptable.

(d) This was generally answered well. The most common error was to state that glu and ala-glu go towards the negative electrode.

(e) (i) Many variant spellings were seen in the 'splitting pattern' column, including the incorrect 'duplet' and 'quadret' which were not awarded credit.

(ii) Many candidates described the difference in such an NMR spectrum when D_2O is added, which was not what the question asked. Other candidates wrongly stated that H↔D exchange happens when $CDCl_3$ is added.

Question 8

(a)   The majority of candidates placed their ticks correctly for lattice energy and enthalpy of solution. Candidates found enthalpy of hydration more difficult.

(b)   Some good answers were seen.

(c) (i)   It is essential in a calculation for candidates to show their working.

(ii)   Many candidates did not appreciate that their calculation initially gave a value for the $\Delta H^{\ominus}_{hyd}$ of **two** moles of Br^- ions.

(iii)   A comparison of ionic radii was usually correct. The comparison of the attractive forces between the two ions and water molecules was awarded much less often.

CHEMISTRY

> **Paper 9701/51**
>
> **Paper 5 Planning, Analysis and Evaluation**

Key messages

Questions **1(a)(iii)**, **1b(iii)**, **3(b)(iii)** and **3(c)(iv)**, tested candidates' understanding of the principles underlying the experimental procedure involved. To produce a response worthy of credit, candidates needed to demonstrate a deep understanding of these principles.

Candidates should be able to perform basic titration calculations and apply the principle in unfamiliar situations. Weaker candidates would benefit from more practise of these.
Only the strongest candidates were able to determine half-lives from a concentration versus time graph. Candidates would benefit from more practise working with graphs.

General comments

The strongest candidates were able to demonstrate a comprehensive understanding of the material assessed. Weaker candidates were unable to access some questions leaving them unanswered.
Candidates should use scientific terminology accurately and use a sharp pencil for graph plotting.

Comments on specific questions

Question 1

(a) (i) The majority of candidates used the supplied density data correctly and understood that the lower layer in the separating funnel would be the aqueous layer.

(ii) The transfer of $10.0\,cm^3$ of the aqueous layer in **step 8** requires the precision provided by volumetric apparatus. A measuring cylinder ($\pm 0.5\,cm^3$) is unsuitable; a burette ($\pm 0.05\,cm^3$), although precise enough, is inappropriate for transfer of a fixed volume of solution. The most appropriate piece of apparatus is a volumetric pipette. A few candidates chose a $25.0\,cm^3$ volumetric pipette instead of $10.0\,cm^3$.

(iii) The strongest candidates answered correctly. Weaker candidates demonstrated confusion about the substances reacting in the titration. Many thought the ethoxyethane was reacting with the sodium hydroxide. Better performing candidates understood that the undissociated butanedioic acid in the ethoxyethane layer can dissociate in the added water and is then able to react with sodium hydroxide. Common incorrect answers included 'to dilute one or both layers', 'to ensure all of the acid has dissolved', 'lower percentage error' and 'to dissolve the indicator'.

(b) (i) Stronger candidates were able to complete this standard titration calculation, which involved: calculating the amount of sodium hydroxide in $27.25\,cm^3$ of $0.5\,mol\,dm^{-3}$ solution used in the titration; using the mole ratio from the equation to calculate the amount of butanedioic acid; dividing by the volume ($10\,cm^3$) to find the concentration.
Weaker candidates commonly answered 0.874 obtained by:
number of moles = 2.81 ÷ 118 = 0.023813559
concentration = moles ÷ volume = 0.023813559 ÷ 0.02725 = $0.874\,mol\,dm^{-3}$.

(ii) The strongest candidates answered correctly, with correct responses commonly beginning with a similar calculation to the one required for **(b)(i)** to obtain the concentration of butanedioic acid in the ethoxyethane layer and then inserting that value, along with their answer to **(b)(i)**, into the expression given for K_{pc}.

(iii)   Many candidates understood there would not be enough solution for multiple titrations. To gain credit, candidates needed to explain why this is the case. Stronger candidates explained the mechanism by which some of the aqueous layer is not available for titration. Weaker candidates misunderstood the situation and referred to not having enough sodium hydroxide (in the burette) to complete further titrations.

(iv)   Good answers clearly explained one of the two methods to allow more than two titrations to be completed: either using smaller aliquots of the aqueous layer in **step 8** or making a larger volume of the aqueous layer in the separating funnel in **step 1**.

Simply suggesting 'increase the volume of the aqueous solution' is ambiguous, as it is unclear whether this refers to **step 1** or **step 8**.

(v)   Stronger candidates used correct terminology to accurately describe the difference between the layers when the student shook the separating funnel compared to what happens when shaking is not done. Weaker candidates were unclear about what chemical was present in the layers.

Question 2

(a)   Stronger answers explained why a capillary tube is used compared to the pipette.

(b)   The majority of candidates recognised that the spots due to the amino acids were colourless/white and therefore invisible to the naked eye. Weaker candidates incorrectly suggested it was possible to identify individual amino acids by the colour produced or that the locating agent was acting as a fixer to stop spots moving.

(c)   Most candidates identified the three amino acids successfully. Weaker candidates selected an incorrect amino acid due to an incorrect calculation of the R_f value.

(d)   Stronger candidates understood that a tripeptide consists of 3 amino acids which could be identical. Common misconceptions were that **'B** was not fully hydrolysed'; '**B** was a dipeptide'; 'one of the amino acids in **B** was not soluble in the solvent'.

(e) (i)   Many candidates understood and used the R_f values correctly in their answer. Stronger candidates were able to show deeper understanding of the process taking place by referring to similarity in affinity to chromatography paper or solubility in the solvent of the two amino acids.

(ii)   The majority of candidates suggested a correct improvement to the given method. Some candidates mis-read the question and suggested an alternative method such as gas/liquid chromatography. The amino acids would have to be converted into more volatile derivatives before this method could be used.

Question 3

(a)   Many candidates demonstrated they understood how to make up a standard solution. The most frequent omission was shaking/inverting to ensure everything is mixed effectively at the end of the process.

(b) (i)   Most candidates were able to identify a thermostatically controlled water bath as the most effective way of maintaining the temperature of the solution.

(ii)   Most candidates could identify the dependent variable.

(iii)   The strongest candidates were able to explain why measuring the loss in mass was not used. Weaker candidates were unaware of the conservation of mass and thought that the production of phenol would increase the mass of the solution.

(c) (i)   The final column in Table 3.1 was completed correctly by almost all candidates. A very small number used ($V_t - t$), which resulted in a column of incorrect data.

(ii) The majority of candidates plotted suitably small points accurately. Weaker candidates plotted large thick crosses or dots, and/or plotted points to the nearest grid line. e.g. (16, 17.7) as (16, 18). Data points should be plotted correctly using a sharp pencil.

(iii) The majority of candidates correctly identified and circled the most anomalous point based on their line of best fit. The weakest candidates incorrectly circled a point on their line of best fit.

(iv) The strongest candidates evaluated whether the volume reading was taken before or after the time stated in the table. Weaker candidates were unable to suggest a valid reason for the error.

(v) The strongest candidates quoted two pairs of (x, y) coordinates, one pair for the first half life and one pair for the second.

A good answer took the following form, with the coordinates read correctly from the candidate's curve of best fit:

first $t_{1/2}$: coordinates	(0, 57.2)	and	(9.8, 28.6)
half-life =	9.8 min		
second $t_{1/2}$: coordinates	(9.8, 28.6)	and	(20.0, 14.3)
half-life =	10.2 min		

Correctly measured and recorded coordinates make the calculation of half-lives straightforward. Weaker candidates held the misconception that two gradients were required.

(vi) Stronger candidates correctly deduced and explained the order of the reaction using their answer to **3(c)(v)**. Weaker candidates were unable to link half-lives to the order of the reaction.

CHEMISTRY

Key messages

- It is important that candidates' numerical answers reflect the appropriate number of significant figures. Most numerical answers should be given to three significant figures, unless indicated otherwise. One significant figure will almost certainly be insufficient.
- Candidates should be reminded of the correct way to draw a line of best fit. Many candidates opt to draw their line of best fit directly from the first point to the last point without due regard to the plotted points. In this paper, the first point was clearly the anomaly and should not have been included on the line of best fit.
- Candidates need to be aware that it is always better to select points from the line which are not coordinates from the table of results. If a mis-plotted coordinate is drawn on the graph, then the error becomes compounded if the candidate selects the erroneous plot.

General comments

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

Many candidates were able to choose a good straight line of best fit, with approximately equal number of points, except for obvious anomalies, each side of the line.

Good answers are characterised by succinct answers.

Comments on specific questions

Question 1

(a) (i)   Nearly all candidates were able to use the mass and density provided to deduce the volume of methyl benzoate to the nearest $0.05\,cm^3$. A few incorrectly converted $1.15\,cm^3$ to $1.20\,cm^3$ as their final answer.

(ii)   Nearly all candidates recognised that a burette was the piece of equipment needed to measure a volume of liquid to the nearest $0.05\,cm^3$. Unacceptable answers included syringes and measuring cylinders.

(iii)   The calculation to determine, effectively, the mass of $0.100\,mol$ NaOH was well done by most candidates.

(b)   The method of making up a set volume of a standard solution from a given mass of solid was generally well known. Dissolving the solid must be done using a volume of distilled water less than the volume of standard solution being made. Frequently, candidates stated 'dissolve the solid NaOH in $100\,cm^3$ of distilled water'; others started from 'aqueous NaOH'. **All** the dissolved moles of NaOH must be transferred into a flask. Weaker answers transferred to measuring cylinders or beakers. The use of a burette or a pipette in this transfer negates the mark as not all the moles of NaOH would be transferred. Many candidates erroneously used a $250\,cm^3$ volumetric flask and incorrectly filled the flask with distilled water.

(c) This was a challenging question for most candidates. The better performing candidates were able to cope well. The question required careful reading of the information and appreciating that only 10 cm^3 of the 100 cm^3 prepared solutions were used. Candidates were required to determine the number of moles of NaOH in each 10 cm^3 of solution and compare this against the number of moles of methyl benzene. Many candidates simply assumed, incorrectly, that as the 10 cm^3 solutions were derived from the initial NaOH(aq) differing by a factor of ten, then the mass of product would differ by the same factor. Better performing candidates were able to realise that the limiting reagent switched from NaOH to methyl benzoate when there was a ten-fold increase in concentration in NaOH(aq).

(d)(i) The reason for the need to use reflux in an organic preparation was generally not well understood. The complete answer was rarely seen. NaOH was not accepted as a volatile substance.

(ii) Most candidates knew that naked flames should not be used in the presence of flammable (named) substances. Inorganic substances such as NaOH or HCl were not accepted as a flammable substance, and neither was benzoic acid as it had not been prepared in step 5 of the method.

(iii) Very few candidates appreciated that anti-bumping granules needed removing before precipitation of the product. Most answers suggested candidates have not met practical work involving anti-bumping granules.

(e)(i) Some candidates knew the idea that an acid-base indicator should be added to the mixture; not all of these candidates suggested that the change in colour of the indicator would confirm acidification.

(ii) Most candidates realised that a precipitate/crystalline solid would be produced as the information was available in the state symbols given in the equations. Additional incorrect observations such as fizzing nullified this mark.

(f) Many candidates realised that more precipitation of benzoic acid would occur. They often could not relate this to how solubility decreases as temperature decreases.

(g) Most candidates described methods for the drying of the benzoic acid. Many answers lacked the extra detail to address the 'ensure' part of the question and left out the idea of achieving a constant mass.

(h)(i) Most candidates correctly answered this question.

(ii) Most candidates provided a correct answer. Some incorrectly used the initial mass of methyl benzoate in their calculation rather than their answer to **(h)(i)**.

Question 2

(a)(i) Nearly all candidates answered this correctly.

(ii) This was correctly answered by most candidates. Some incorrect answers did not appreciate that $K_w = [H^+]^2$. Others made arithmetic errors in either squaring their answer to **(a)(i)** or giving incorrect indices.

(iii) Most candidates introduced the idea of proportionality, which given the insufficient details provided in the information, was not credited. These candidates nearly all went on to correctly state that an increase in temperature produced an increase in K_w.

(b)(i) Most results tables were correct. A significant number were not in standard form. Rounding errors, of which there were a quite a few, resulted in a loss of credit.

(ii) The majority of candidates plotted all points correctly. The plot at $(3.10 \times 10^{-3}, -13.26)$ occasionally appeared at $(3.01 \times 10^{-3}, -13.26)$. Most candidates drew a sensible line of best fit which clearly ignored the anomaly. A significant number opted to draw a line from the 'first point to last point' i.e. from $(2.92 \times 10^{-3}, -12.84)$ to $(3.53 \times 10^{-3}, -14.53)$ despite the anomalous nature of the first point, $(2.92 \times 10^{-3}, -12.84)$ being apparent.

(iii) The anomalous point was identified by most candidates. Candidates who drew a 'first point to last point' line of best fit found it more difficult to identify their most anomalous point.

(iv) Most candidates could explain the anomaly identified in **(b)(iii)**. Weaker responses struggled to compare the recorded and actual temperatures and often lacked detail about which temperature they were referring to (measured or actual), so were unable to obtain credit for their answer.

(v) Nearly all candidates were able to calculate a gradient based upon their chosen coordinates. A significant number of candidates omitted the power of $\times 10^{-3}$ in their x coordinates and a large number gave an unsuitable range between the pairs of coordinates. A few selected points from the table that were not on their line of best fit and there were also some who misread coordinate values from the graph. A small number gave the gradient to an unsuitable number of significant figures.

(vi) The majority of candidates successfully used their gradient value to calculate ΔH. A very small minority gave an incorrect sign and there 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.

CHEMISTRY

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