CHEMISTRY

> **Paper 9701/11**
> **Multiple Choice**

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

General comments

This examination paper provided an accessible challenge to the candidates. There were many pleasing performances, and some really outstanding ones.

Sixteen questions can be said to have been found to be easier. Seventy per cent or more of candidates chose the correct responses to each of **Questions 1**, **2**, **4**, **7**, **8**, **10**, **14**, **17**, **21**, **27**, **29**, **30**, **32**, **34**, **38** and **39**. Six questions can be said to have been found to be particularly difficult. Fewer than 47 per cent of candidates chose the correct responses to each of **Questions 6**, **12**, **20**, **23**, **31** and **33**.

Comments on specific questions

Question 6

46% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. The choice of **B** suggests candidates evaluated the angles on the diagram, rather than the angles in histamine. x will be approximately 107° and therefore smaller than y which will be approximately 109.5°.

Question 12

45% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **A**, chosen by 21% of candidates. 0.0125 mol of oxygen will react with 0.05 mol of a group 1 metal or 0.025 mol of a group 2 metal. The only sample that fits one of these descriptions is 1.15 g of sodium.

Question 20

21% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 43% of candidates. Candidates who chose **A** may have missed the phrase "all of the bonds remain in the places shown". If benzene had this structure there would be two 1,2 isomers, one 1,3 isomer and one 1,4 isomer. The two 1,2 isomers would have the chlorine atoms positioned across a single bond in one isomer and across a double bond in the other isomer.

Question 23

46% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 26% of candidates. The aqueous acid would hydrolyse the ester group shown at the top of the strobilurin diagram, leaving a $–CO_2H$ group. This product is "compound X". The H_2/Ni would then reduce all of the C=C bonds, but not the C=O bond of the carboxylic acid group, leaving "compound Y" which is the structure shown in **A**.

Question 31

25% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 41% of candidates. Candidates first had to work out that X^+ and Y^+ are boron ions and Z^+ is an aluminium ion. Working out the numbers of protons, neutrons and electrons in X^+, Y^+ and Z^+ shows that statement 1 is correct and statement 3 is incorrect. Evaluating the sum $((10 \cdot 15.52)+(11 \cdot 74.48))/90$ then shows that statement 2 is correct, hence the answer is **B**.

Question 33

35% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 46% of candidates. The question therefore rested, for many candidates, on the truth or otherwise of statement 2. Enthalpy change of hydration is indeed always negative, as bonds are formed between the gaseous ions and water molecules, so the answer is **B**.

CHEMISTRY

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

General comments

This examination paper provided a suitable challenge to the candidates. There were many pleasing performances, and some really outstanding ones.

Fifteen questions can be said to have been found to be easier. 60 per cent or more of candidates chose the correct responses to each of **Questions 1**, **2**, **3**, **4**, **6**, **12**, **13**, **17**, **19**, **22**, **24**, **25**, **28**, **30** and **40**. Six questions can be said to have been found to be particularly difficult. Fewer than 40 per cent of candidates chose the correct responses to each of **Questions 8**, **26**, **27**, **29**, **35** and **37**.

Comments on specific questions

Question 8

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 29% of candidates. If a fixed mass of gas is behaving ideally the sum PV/RT gives a constant value. For both the conditions given in the question PV/RT = 6.418 (if volumes of $1\,dm^3$ and $0.5\,dm^3$ are assumed.) Therefore the gas is behaving ideally.

Question 26

36% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**, chosen by 40% of candidates. This suggests that the majority of candidates worked out the formula of the correct diester, but that those who incorrectly chose **B** were unsure as to how the ester link should be written in a structural formula.

Question 27

26% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 33% of candidates. This shows that most candidates realised it cannot be **A** or **B**, as reaction with HCN would give a product with five carbon atoms. It was then necessary to find the products of mild oxidation of propan-1-ol, which gives propanal, and propan-2-ol, which gives propanone. Of these two carbonyl compounds only propanal reacts with HCN to give 2-hydroxybutanenitrile.

Question 29

29% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 41% of candidates. Candidates who chose **B** may have selected the two carboxylic acids only. However, the two esters will be hydrolysed by aqueous sodium hydroxide, giving the sodium salt of a carboxylic acid as one product, so the answer is four.

Question 35

21% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 36% of candidates. This suggests that for many candidates the question hinged on the truth or otherwise of statement 2. It can be imagined that 2 g is heated, consisting of 1 g of $MgCO_3$ and 1 g of $BaCO_3$. Only the $MgCO_3$ decomposes on heating. 1 g of $MgCO_3$ loses $(44/84.3)\,g = 0.522\,g$ of CO_2. This is 26% of the total 2 g to 2SF. Statement 2 is true.

Question 37

38% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answers were **A**, chosen by 25% and **C**, chosen by 26%. Hot, concentrated manganate (VII) will produce CO_2 from the two $=CH_2$ groups, so statement 1 is true. It will produce CH_3COCH_3 from the $(CH_3)_2C=$ group, so statement 2 is true. However, there is no $CH_3CH=$ group, so CH_3CO_2H will not be produced, so statement 3 is untrue.

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Paper 9701/13
Multiple Choice

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Comments on specific questions

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46% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. The choice of **B** suggests candidates evaluated the angles on the diagram, rather than the angles in histamine. x will be approximately 107° and therefore smaller than y which will be approximately 109.5°.

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Question 33

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CHEMISTRY

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Paper 9701/21
AS Structured Questions
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Key messages

Candidates should be encouraged to use the information presented in a question as well as their knowledge of the subject to produce relevant responses. Care needs to be taken to ensure that chemicals are named and/or identified correctly.

General comments

Answers were generally presented clearly and logically. There were some exceptional and many very good performances on this paper. These candidates demonstrated a very good understanding of the subject material and applied their knowledge accurately. Candidates can improve their level of response by matching the answer to the question asked rather than reproducing knowledge related to the relevant topic without addressing the specific question. The organic chemistry questions proved to be the most challenging aspect for many candidates.

Comments on specific questions

Question 1

A significant number of candidates worked through this structured calculation logically and identified the element **X** from their calculated atomic mass.

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

(b)   The majority of candidates could represent the balanced chemical equation for the reaction of sodium hydroxide with hydrochloric acid.

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

(d)   Many candidates calculated the amount of sodium hydroxide neutralised in the titration. A significant number of responses gave the total amount of sodium hydroxide added in excess.

(e)   Many candidates correctly deduced the amount of HCl produced.

(f)   The majority of candidates correctly used the stoichiometry of equation 1 to deduce that the amount of the Group 14 chloride would be one quarter of the amount of HCl produced.

(g)   Finding the molecular mass from the mass of the sample and the answer to **(f)** was correctly completed in the majority of answers.

(h)   Most candidates that had calculated a value for the molecular mass to be greater than 142 successfully calculated the atomic mass of **X** and identified the element in the Periodic Table with that value. Others correctly identified the Group 14 element whose atomic mass was closest to the value obtained.

By appreciating that silicon is the only Group 14 chloride that will react with water to form acid, enabled some to review their final answer and refer to earlier parts of the question to find and correct mistakes in their working. Analysis of calculations and all the information provided to confirm that the answer derived makes sense should be encouraged.

Question 2

(a) (i)   The definition was generally well known. Occasional responses referred to the energy required for the reaction despite the exothermic nature of all combustion reactions. General reference to an oxidation reaction was also seen, in spite of the fact that not all oxidation reactions are combustion reactions.

(ii)   Many equations showed the products of complete combustion of ethanol as carbon dioxide and water. There was a significant number of responses in which the oxygen atom in the alcohol was ignored when balancing this equation.

(b) (i)   The appropriate equation $q=mc\Delta T$ was often seen. Common mistakes in this calculation included converting the temperature rise into a kelvin temperature and using the mass of the ethanol and water as the value for m.

(ii)   The negative value for the enthalpy change of combustion was often not appreciated. A common error was to take the value calculated in **2(b)(i)** and divide it by one thousand.

(iii)   There were some very clear responses, which showed an appreciation of why the experimental value may be lower than the true value. Heat loss and incomplete combustion were common correct responses. The idea of using impure ethanol and evaporation of some of the ethanol in the sample was also seen. When data is provided in a question of this type it is assumed that the results obtained are reliable. Responses that evaluated potential errors in technique or reviewed the accuracy of the equipment were seen.

(c) (i)   A relatively small number of candidates constructed a labelled energy cycle. Although many responses appreciated the stoichiometry involved within the cycle, there was confusion in terms of the direction of arrows used to describe the processes. Some cycles were drawn as though enthalpy of formation data had been provided.

(ii)   Despite the problems in constructing a Hess' Cycle, many candidates were able to correctly calculate the enthalpy change of formation for the reaction.

Question 3

(a) (i)   The trend and explanation for the change in size of atomic and ionic radius down a group in terms of increasing number of electron shells and the increased shielding effects result in weaker nuclear attraction was a common response.

(ii)   Identification of the lines representing the atomic and ionic radii of the Group 2 elements was described by many. Some explanations were quite general and not specific to the Group 2 elements. There were a small number of candidates who incorrectly described the nuclear charge of the ion being greater than that of the corresponding atom.

(b) (i)   Only a small number of responses showed that the only Group 2 salts that break down on heating to form a brown gas are the nitrates. Some candidates assumed that if a brown gas was made on heating the salt must be a bromide.

(ii)   General equations for the reaction of sulfuric acid with barium hydroxide were common even though the question specifically asked for an ionic equation for the formation of the white precipitate.

(iii)   Many candidates who correctly represented the formula of a Group 2 nitrate constructed balanced equations showing the thermal decomposition of the salt.

(c) (i)   The ionic equation for the reaction of calcium hydroxide with acid was well known but correct answers showing the reaction of calcium carbonate with acid were less common. In this case, either the equations were not balanced or the carbonate ions were sometimes shown with a –1 charge. Full equations showing the neutralisation of calcium carbonate and calcium hydroxide with a variety of mineral acids were common answers, even though the ionic equations were specifically asked for in the question.

(ii)   Better performing candidates explained why calcium carbonate is a better choice in areas of high rainfall. The difference in solubility of the two compounds and a consequence of this difference were given by these candidates. These candidates tended to describe the insolubility of calcium carbonate resulting in less of it being washed away from the soil or lasting longer or reacting more slowly. Some responses described general advantages for using calcium carbonate, which were not related to high rainfall.

(d)   The formulae of the magnesium containing products for the reactions with water and steam were well known. Only the formulae were required but many gave equations for the reaction.

Question 4

(a) (i)   The stem of the organic molecule and its stem suffix and prefix were usually identified correctly. The identification of the position of the double bond, so that the number in the name was the lower number, did not always occur.

(ii)   A correct definition of the term stereoisomerism was only given by a relatively small number of candidates. The key part to the definition, the identical structural formula of these molecules, was omitted by many.

(iii)   Many answers included the identification of the four stereoisomers with no attempted explanation of the key parts of the structure that allowed for the existence of the different stereoisomers. For those candidates who gave an explanation, it was common to see the double bond and the chiral carbon as key features of the structure. Only the better performing candidates gave clear explanations of the presence of two different groups attached to each carbon of the double bond.

(b) (i)   Those candidates who drew the structure out fully were more successful at naming the compound; by doing this it was much easier to identify the longest carbon chain and the position of the double bond.

(ii)   The majority of candidates recalled that an alkene would react to form the corresponding diol in the presence of cold, dilute, acidified manganate(VII) ions and were able to draw the skeletal formula of this molecule. Only a very small number of candidates represented the molecule with the incorrect connectivity between the carbon skeleton and the hydroxy group.

(iii)   Naming the product of the reaction of the alkene with hot, concentrated, acidified manganate(VII) ions proved more challenging to candidates than **4(b)(i)**. There were some candidates who correctly identified the functional group of the product as a ketone with no attempt made to name the product as required by the question.

(iv)   Many candidates correctly identified the three repeat units of the addition polymer made and included a bond at each end of the structure.

(c) (i) Some candidates were able to correctly identify the number that indicated the position of the double bond and the methyl group when naming this structure.

(ii) In general, the details for the mechanism were well known; the dipole on hydrogen bromide was correctly described and arrows were seen coming from the double bond towards the hydrogen of the hydrogen bromide and from the hydrogen bromide bond to the bromine atom. Many answers correctly showed the tertiary carbocation formed. It was less common to see the arrow from the lone pair of electrons on the bromide ion to the positively charged intermediate in the final stage of the mechanism.

(iii) Only a very small number of candidates were able to explain fully why the tertiary halogenoalkane was the major product. Some responses identified that the tertiary intermediate formed was more stable. Many candidates recognised that the methyl groups were electron donating but only a small number of candidates realised the significance of *more* methyl groups on this intermediate being key to the explanation. General references to stabilisation of the charge were occasionally seen but only in the clearest explanations was the more precise description of reducing the charge density on the C^+ discussed.

Question 5

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

(b) Many candidates identified the correct reagent required to oxidise the alcohol to the carboxylic acid but not all responses included the acid conditions necessary. Reflux conditions were correctly described by many.

(c) Many candidates identified the correct reagent required to oxidise the alcohol to the aldehyde. A small number appreciated the need to distil the reaction mixture.

(d) Correct identification and naming of the ester made was achieved by many candidates. No attempt was made in some responses to name the product.

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Paper 9701/22
AS Structured Questions

Key Messages

Candidates should be reminded to read questions carefully and check their answers thoroughly. Clear distinctions are needed when using subject-specific terms; especially with regard to the key distinctions between different types of bonding and intermolecular forces. Many candidates confuse these ideas when discussing the melting/boiling points and molecular structures of substances. Candidates should also be reminded that all working in calculations should be shown to ensure that due credit can be awarded.

Candidates should also beware of offering multiple answers to questions, as an incorrect response in a second answer can invalidate an otherwise correct first attempt. Candidates must avoid simply repeating the question when asked for an explanation. When a question includes the command word 'Explain' there will usually be more than one mark available and candidates should make sure that more than a single statement is offered. A classic example of this is in questions asking for an explanation of why one ionisation energy is higher than another; it is not enough to simply say that 'more energy is needed to remove the electron' as this is effectively a repeat of the question.

General Comments

Many candidates found **Question 3** challenging due to confusions between the various types of bonding and intermolecular forces, with covalent bond strength often thought to be related to melting and boiling points of molecular substances. Calculations were generally well done. Some candidates were not confident in their use of organic conversions.

Comments on Specific Questions

Question 1

(a) Almost all candidates correctly completed this first part of the calculation.

(b) (i) Most candidates could produce a correctly balanced equation, although some candidates suggested incorrect products such as HCO_3 or Na_2Cl.

    (ii) Most candidates could use the volume and concentration given in the stem of part **(b)** to complete this calculation, although some candidates selected the wrong data. The use of underlining in the stem of a question is recommended to help organise and reference information given.

    (iii) Some candidates incorrectly tried to use the M_r of HCl in this calculation instead of recognising that they needed to use the answer to **(b)(ii)** and the ratio in their equation.

(iv)   A significant number of candidates made the mistake of carrying out the subtraction here, that is needed in **(b)(v)**, instead of recognising that the volume of solution used in the solution was 1/10th of the volume of the original solution made up.

(v)   Candidates needed to realise that the titration determines the excess acid remaining after some had reacted with the metal. It is at this point at which the subtraction was needed.

(vi)   Candidates who had followed the sequence of the calculation successfully to this point were mostly able to finish correctly here and in **(b)(vii).**

Question 2

(a)   Most candidates could label the diagram correctly although some answers were reversed and, in some cases, the arrows pointed in the wrong direction.

(b) (i)   Most candidates recognised that the data given in the stem suggested that use of pV = nRT was appropriate here, but some ignored this. Most candidates were also able to express their answer to three significant figures as asked but some overlooked this requirement.

(ii)(iii) and **(iv)**
Some candidates seemed to be confused by the need to express their answer in terms of 'n' but most could answer this question, and parts **(iii)** and **(iv)** correctly.

(v)   Some candidates did not notice that the value for the mole fraction of N_2O_4 was given in this question so tried to use data from elsewhere in the question, which was seldom successful.

(vi)   The commonest error was the use of square brackets, which should only be used in an expression for K_c and never in an expression for K_p.

(vii)   The concept of mole fraction was not well understood as even those candidates who did notice that the value of 0.4 was given often then did not appreciate that the mole fraction of NO_2 must therefore be 0.6. Most candidates gave the correct units, but there was some confusion with mol dm^{-3} and with kPa.

Question 3

(a) (i) Some candidates did not appreciate the need to mention both the increasing nuclear charge and the similar/almost constant shielding across the period. Some candidates also contradicted their answer by stating that the radius stays constant across the period.

(ii) The distinction between the responses needed to the two sections of this question exemplify the importance of using the correct, technical terminology. To explain the decrease between Group 2 and Group 3 it must be clear that candidates are aware that the Group 3 element has its outermost electron in the p <u>sub</u>shell and not the shell, which is at a higher energy level then the s subshell electron of the Group 2 element.

To explain the decrease between Groups 5 and 6 it must, in turn, be clear that the candidate is describing that the Group 6 element has a pair of electrons in a p <u>orbital</u> and that it is the repulsion between these two electrons that explains the observation.

(iii) This proved challenging to many candidates who mis-interpreted the question and attempted to explain why the noble gases have the highest ionisation energies in their period rather than, as the question required, explaining the decrease down the group in terms of increased shielding or distance, which leads to reduced attraction between nucleus and outer electrons.

(b) (i) Quite a few candidates negated a correct reference to metallic bonding in the Group 2 element being stronger than in the Group 1 element by also referring to intermolecular forces or some alternative bonding type. Some candidates gave a correct explanation, in terms either of the greater charge of the Group 2 cation or the greater number of delocalised electrons.

(ii) Candidates found this a challenging question. A number of good answers were seen, which usually involved an explanation based around the increase in charge from 2+ to 3+ being relatively less significant than that from 1+ to 2+.

(iii) A common error here was for candidates to imply in their answers that covalent bonding is somehow related to this pattern; when what is needed is an explanation in terms of the strengths of intermolecular forces. Candidates must also make sure they read and answer the whole question as the easiest, first marking point was often over-looked as candidates did not properly describe the pattern of an increase (from P to S) followed by a decrease (from S to C*l* to Ar).

(iv) Most candidates were able to describe the structure as giant covalent.

Question 4

(a) (i) Most candidates could name this compound correctly.

(ii) Many candidates were able to draw the two stereoisomers.

(iii) The same structure was often drawn twice or candidates included 2-bromobutane as one of their suggestions, despite the question asking for three <u>other</u> structures.

(b) (i) This name proved much more challenging than in **4(a)(i)**. Candidates are advised to do a rough sketch of a relatively complex molecule to help visualise it before attempting to name it.

(ii) Candidates were required to recognise here that a tertiary halogenoalkane will react by the S_N1 mechanism. It is vital to remember that curly arrows must be carefully drawn and positioned such that it is clear they always start either at a bond or at a lone pair.

(iii) Most candidates correctly named the mechanism.

(c) (i) Most candidates correctly identified the reagent, although there was some confusion with the dehydration of alcohols (which also produces alkenes) leading to H_2SO_4 being suggested. Some candidates incorrectly gave (aq) for the conditions.

(ii) Elimination was correctly identified by most candidates.

(iii) Most candidates could draw two structures, although some candidates incorrectly included Br in their structures. The third structure suggested was, however, often either a repeat of one of the first two structures (e.g. but-1-ene or but-2-ene was often drawn twice; once with the double bond on the right and once with it on the left) or a branched structure. Few candidates recognised that but-2-ene could be drawn in either the cis- or trans- configuration.

Question 5

All parts of this question were well answered by most candidates.

CHEMISTRY

**Paper 9701/23
AS Structured Questions**

Key messages

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(d)   Many candidates calculated the amount of sodium hydroxide neutralised in the titration. A significant number of responses gave the total amount of sodium hydroxide added in excess.

(e)   Many candidates correctly deduced the amount of HC*l* produced.

(f)   The majority of candidates correctly used the stoichiometry of equation 1 to deduce that the amount of the Group 14 chloride would be one quarter of the amount of HC*l* produced.

(g)   Finding the molecular mass from the mass of the sample and the answer to **(f)** was correctly completed in the majority of answers.

(h)   Most candidates that had calculated a value for the molecular mass to be greater than 142 successfully calculated the atomic mass of **X** and identified the element in the Periodic Table with that value. Others correctly identified the Group 14 element whose atomic mass was closest to the value obtained.

      By appreciating that silicon is the only Group 14 chloride that will react with water to form acid, enabled some to review their final answer and refer to earlier parts of the question to find and correct mistakes in their working. Analysis of calculations and all the information provided to confirm that the answer derived makes sense should be encouraged.

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(a) (i)   The definition was generally well known. Occasional responses referred to the energy required for the reaction despite the exothermic nature of all combustion reactions. General reference to an oxidation reaction was also seen, in spite of the fact that not all oxidation reactions are combustion reactions.

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(ii)   Despite the problems in constructing a Hess' Cycle, many candidates were able to correctly calculate the enthalpy change of formation for the reaction.

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(b) (i)   Only a small number of responses showed that the only Group 2 salts that break down on heating to form a brown gas are the nitrates. Some candidates assumed that if a brown gas was made on heating the salt must be a bromide.

(ii)   General equations for the reaction of sulfuric acid with barium hydroxide were common even though the question specifically asked for an ionic equation for the formation of the white precipitate.

(iii) Many candidates who correctly represented the formula of a Group 2 nitrate constructed balanced equations showing the thermal decomposition of the salt.

(c) (i) The ionic equation for the reaction of calcium hydroxide with acid was well known but correct answers showing the reaction of calcium carbonate with acid were less common. In this case, either the equations were not balanced or the carbonate ions were sometimes shown with a –1 charge. Full equations showing the neutralisation of calcium carbonate and calcium hydroxide with a variety of mineral acids were common answers, even though the ionic equations were specifically asked for in the question.

(ii) Better performing candidates explained why calcium carbonate is a better choice in areas of high rainfall. The difference in solubility of the two compounds and a consequence of this difference were given by these candidates. These candidates tended to describe the insolubility of calcium carbonate resulting in less of it being washed away from the soil or lasting longer or reacting more slowly. Some responses described general advantages for using calcium carbonate, which were not related to high rainfall.

(d) The formulae of the magnesium containing products for the reactions with water and steam were well known. Only the formulae were required but many gave equations for the reaction.

Question 4

(a) (i) The stem of the organic molecule and its stem suffix and prefix were usually identified correctly. The identification of the position of the double bond, so that the number in the name was the lower number, did not always occur.

(ii) A correct definition of the term stereoisomerism was only given by a relatively small number of candidates. The key part to the definition, the identical structural formula of these molecules, was omitted by many.

(iii) Many answers included the identification of the four stereoisomers with no attempted explanation of the key parts of the structure that allowed for the existence of the different stereoisomers. For those candidates who gave an explanation, it was common to see the double bond and the chiral carbon as key features of the structure. Only the better performing candidates gave clear explanations of the presence of two different groups attached to each carbon of the double bond.

(b) (i) Those candidates who drew the structure out fully were more successful at naming the compound; by doing this it was much easier to identify the longest carbon chain and the position of the double bond.

(ii) The majority of candidates recalled that an alkene would react to form the corresponding diol in the presence of cold, dilute, acidified manganate(VII) ions and were able to draw the skeletal formula of this molecule. Only a very small number of candidates represented the molecule with the incorrect connectivity between the carbon skeleton and the hydroxy group.

(iii) Naming the product of the reaction of the alkene with hot, concentrated, acidified manganate(VII) ions proved more challenging to candidates than **4(b)(i)**. There were some candidates who correctly identified the functional group of the product as a ketone with no attempt made to name the product as required by the question.

(iv) Many candidates correctly identified the three repeat units of the addition polymer made and included a bond at each end of the structure.

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(c) (i) Some candidates were able to correctly identify the number that indicated the position of the double bond and the methyl group when naming this structure.

(ii) In general, the details for the mechanism were well known; the dipole on hydrogen bromide was correctly described and arrows were seen coming from the double bond towards the hydrogen of the hydrogen bromide and from the hydrogen bromide bond to the bromine atom. Many answers correctly showed the tertiary carbocation formed. It was less common to see the arrow from the lone pair of electrons on the bromide ion to the positively charged intermediate in the final stage of the mechanism.

(iii) Only a very small number of candidates were able to explain fully why the tertiary halogenoalkane was the major product. Some responses identified that the tertiary intermediate formed was more stable. Many candidates recognised that the methyl groups were electron donating but only a small number of candidates realised the significance of *more* methyl groups on this intermediate being key to the explanation. General references to stabilisation of the charge were occasionally seen but only in the clearest explanations was the more precise description of reducing the charge density on the C^+ discussed.

Question 5

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

(b) Many candidates identified the correct reagent required to oxidise the alcohol to the carboxylic acid but not all responses included the acid conditions necessary. Reflux conditions were correctly described by many.

(c) Many candidates identified the correct reagent required to oxidise the alcohol to the aldehyde. A small number appreciated the need to distil the reaction mixture.

(d) Correct identification and naming of the ester made was achieved by many candidates. No attempt was made in some responses to name the product.

CHEMISTRY

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Paper 9701/31
Advanced Practical Skills 1

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Key messages

Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper before the start of the examination.
Candidates should be reminded to write their answers legibly in dark blue or black pen.
Candidates should use the relative atomic values, as given in the Question Paper, for calculations.
Candidates should ensure they show significant figures appropriate for the experimental technique employed when providing answers to their calculations.
Descriptions of observations in Qualitative Analysis should be precise and include physical state and colour, if appropriate.

Comments on specific questions

Question 1

(a) The vast majority of the candidates successfully completed the practical work.

(b) Where relative atomic masses are used these must be to the degree of accuracy of those quoted in the Periodic Table printed in the Question Paper.

(c) Any practical method that significantly limited the loss of carbon dioxide was accepted.

Question 2

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to $0.05\,cm^3$. Candidates gaining two titres within $0.10\,cm^3$ should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b) The majority of candidates calculated a suitable value for the volume of **FA 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) There were many good answers to this section, showing that some candidates had prepared well. The majority of candidates performed well in parts **(i)** to **(iv)**. A number reversed the subtraction in **(v)** and/or did not divide by 2 in **(vi).** This meant that the calculated percentage purity in some cases exceeded 100%.

(d) A significant number of candidates were able to explain the effect that the loss of carbon dioxide would have on the calculated percentage purity in **Question 1**. Few realised that in **Question 2** the constancy of the hydrochloric acid that reacted meant that there was no change in the percentage purity.

Question 3

There were some well recorded observations and logical conclusions seen. Some candidates seem not always to realise what gases could be given off and therefore for what to test when, for example, solids are heated.

(a)   Many candidates recognised the ions present in **FA 6** but those present in **FA 5** were identified much less often. Few candidates observed the brown gas or the blue solution when acid was added to **FA 5** that had been heated. In the limewater test for carbon dioxide, candidates should state a positive result as showing both colour and state i.e. white precipitate/milky. Cloudy alone is not acceptable as this does not indicate specifically that the precipitate is white. If the question states that 'unknown' should be used where it has not been possible to positively identify an ion then candidates should feel secure in doing so.

(b)   Since the anion was stated as being one of those listed on page 11 it was necessary to consider any of the halides, nitrate or nitrite. Most candidates chose to use the silver nitrate test and to test with aqueous sodium hydroxide to show the presence of nitrite or nitrate. Few recognised that in order to distinguish between these two, a mineral acid must be used. Better performing candidates provided a clear layout that showed the test, then observation and the conclusion.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper before the start of the examination. This is particularly important where Centres are sharing a venue.
Candidates should be reminded to write their answers legibly in dark blue or black pen.
Candidates should ensure they show significant figures appropriate for the experimental technique employed when providing answers to their calculations.

Comments on specific questions

Question 1

The vast majority of the candidates successfully completed the practical work.

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to $0.05\,cm^3$. Candidates gaining two titres within $0.10\,cm^3$ should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b) The majority of candidates calculated a suitable value for the volume of **FA 2** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) There were many good answers to this section showing that some candidates had prepared well. A significant number of candidates multiplied **(ii)** by 1000/250 instead of 1000/25. The dilution factor in **(iv)** also caused problems for some candidates, with many of these compounding two errors and thus appearing to reach the correct answer.

Question 2

There were Centres where the supervisor did not provide times for the formation of the blue-black colour.

(a) A significant number of candidates did not record their times to the nearest second as instructed; 32.0 would be incorrect, 32 would be correct. However, a large majority of candidates gained credit for accuracy.

(b) Most candidates answered **(i)** correctly; fewer used the correct total volume in **(ii)**. Many used their answer to **(ii)** correctly in completing the calculations in **(iii)** and **(iv)**.

(c) Most candidates reported a shorter time for the blue-black colour to appear and gave the correct ratio of time **(a)**/time **(c)**.

(d)   In **(i)**, some candidates only stated that the time in **(c)** was less than the time in **(a)** without offering an explanation as instructed. Others confused time and rate giving answers such as 'half the volume of sodium thiosulfate was used' in **(c)**, making the time (or the reaction) approximately twice as fast. In **(ii)**, some candidates mistakenly suggested that the addition of water in **(c)** would increase the total volume used and many agreed with the student. The most commonly seen correct explanation was that the measuring cylinder was used 6 times in **(c)** instead of 5 times or that smaller volumes were measured in **(c)** compared to **(a)**. Not all candidates then went on to state that the error would be greater in **(c)**.

Question 3

There were many excellent answers to this question though some candidates did not seem to have read the general instructions at the top of the page.

(a)   A large majority of candidates provided a suitable table for their results and selected appropriate reagents. The observations for **FA 7** and **FA 10** were usually correct; some candidates possibly did not add sufficient aqueous ammonia for the precipitate with **FA 7** to dissolve. There was a measure of confusion about the colours of the precipitates with **FA 8** and **FA 9** and few candidates reported the colour of the solution formed when excess aqueous sodium hydroxide was added to **FA 9**.

(b)   Some candidates incorrectly stated that the solution turned dark brown or did not note the effervescence. Some candidates did not test the gas evolved. Many candidates correctly tested for and identified oxygen.

(c)   Most candidates noted effervescence in **(i)** but then did not give the colour of the gas or of the solution. There were candidates who claimed the gas was carbon dioxide as limewater turned milky so concluded the anion was carbonate in **(ii)**. In **(iii)**, a significant number of candidates either omitted that the mixture required warming or did not give the full formula for sodium hydroxide; OH^- is not sufficient. Some candidates suggesting that the anion in **FA 11** was chloride, sulfate or sulfite then claimed results to fit their choice rather than carry out their test and obtain a negative result.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

Candidates should be given the opportunity to practise the Qualitative Analysis of organic compounds as well as inorganic compounds and be given appropriate feedback with the help of past papers, mark schemes and examiner reports.

Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper. This is particularly important where Centres are sharing a venue.

Candidates should be reminded to write their answers legibly in dark blue or black pen.

Comments on specific questions

Question 1

(a)   Most candidates recorded gas volumes that were on the burette scale and the accuracy in their volumes was generally reasonable. Some did not record the mass of magnesium as instructed.

(b)   This section was generally answered well, though some candidates did not convert cm^3 to dm^3 in their calculation in **(i)** or gave the answer to an inappropriate number of significant figures. Part **(ii)** was also answered correctly by many. Some who had recorded a mass of magnesium in **(a)** chose to use the default mass.

(c)   Credit was most commonly awarded for the percentage error in the mass of magnesium in **(i)**. A common mistake in the error calculation of the gas volume was to use an individual reading error for the burette. There were many candidates who gave a correct modification in **(ii)**.

(d)   Many candidates focused on how a lower rate of reaction would affect the volume of gas or tried to answer in terms of collision rate, activation energy or equilibrium position. Many did not go on to answer in terms of perceived moles of gas collected or magnesium reacting at the lower temperature.

Question 2

(a)   Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to $0.05\,cm^3$. Candidates gaining two titres within $0.10\,cm^3$ should be encouraged to continue with the rest of the paper rather than performing a subsequent titration. Many candidates completed the titration well, with correctly headed data tables and clearly presented readings and titres.

(b)   The majority of candidates calculated a suitable value for the volume of **FB 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c)   Many candidates answered this calculation correctly. The most common errors were the omission of /106 in **(i)** and the use of 25 cm^3 instead of the titre value in **(iii)**. Candidates who obtained an answer greater than 0.03 in **(iii)** usually subtracted incorrectly in **(v)** to avoid a negative value.

(d)   Few candidates answered either part correctly. Many made a good start in **(i)** by stating less acid would be required but either did not comment that this would be half the volume or that the reason was the 1:1 mole ratio of reactants. Most candidates were unable to consider the effect of carbon dioxide and water vapour in the air on the concentration of aqueous sodium hydroxide. Common incorrect answers included sodium hydroxide would be oxidised or would decompose.

Question 3

Candidates appeared more comfortable experimenting with inorganic rather than organic compounds. They should be reminded to include state changes as well as colour changes occurring during a reaction.

(a)   Few candidates answered **(i)** fully correctly and the unsuccessful collection of observations affected the identification of the organic compounds in **(ii)**. Many candidates were successful in **(iii)** showing good knowledge of the results of the test with 2,4-DNPH. Fewer candidates answered **(iv)** correctly. Of those suggesting Fehling's reagent some did not specify that a precipitate would be formed with propanal and only gave a colour. A number of candidates did not appreciate that the triiodomethane test had already been carried out or selected inappropriate reagents such as potassium dichromate.

(b)   Many candidates correctly observed the blue precipitate in **(i)** though some described it as dark blue. Parts **(ii)** and **(iii)** were also frequently correct, though some candidates wrote 'it turned black' or 'it turned blue/green'; these statements were ambiguous. The majority of candidates noted effervescence in **(iv)** but did not report the changes in appearance of the aluminium or solution. A number of candidates incorrectly identified ammonia. Few candidates identified **(v)** as the brown gas, NO_2, was not often reported or else given as NO_3^-. A few candidates correctly identified both gases but more 'identified' ammonia and/or carbon dioxide claiming evidence that was not credible. The poor performance in **(v)** affected the identification of the anion in **FB 8** so **(vi)** was rarely awarded. Many candidates realised that the reaction was between Cu^{2+} and OH^- ions but either did not balance the equation or omitted state symbols so few were successful in **(vii)**.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper before the start of the examination.

Candidates should be reminded to write their answers legibly in dark blue or black pen.

Candidates should use the relative atomic values, as given in the Question Paper, for calculations.

Candidates should ensure they show significant figures appropriate for the experimental technique employed when providing answers to their calculations.

Descriptions of observations in Qualitative Analysis should be precise and include physical state and colour, if appropriate.

Comments on specific questions

Question 1

(a)   The vast majority of the candidates successfully completed the practical work.

(b)   Where relative atomic masses are used these must be to the degree of accuracy of those quoted in the Periodic Table printed in the Question Paper.

(c)   Any practical method that significantly limited the loss of carbon dioxide was accepted.

Question 2

(a)   Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to $0.05\,cm^3$. Candidates gaining two titres within $0.10\,cm^3$ should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b)   The majority of candidates calculated a suitable value for the volume of **FA 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c)   There were many good answers to this section, showing that some candidates had prepared well. The majority of candidates performed well in parts **(i)** to **(iv)**. A number reversed the subtraction in **(v)** and/or did not divide by 2 in **(vi).** This meant that the calculated percentage purity in some cases exceeded 100%.

(d)   A significant number of candidates were able to explain the effect that the loss of carbon dioxide would have on the calculated percentage purity in **Question 1**. Few realised that in **Question 2** the constancy of the hydrochloric acid that reacted meant that there was no change in the percentage purity.

Question 3

There were some well recorded observations and logical conclusions seen. Some candidates seem not always to realise what gases could be given off and therefore for what to test when, for example, solids are heated.

(a) Many candidates recognised the ions present in **FA 6** but those present in **FA 5** were identified much less often. Few candidates observed the brown gas or the blue solution when acid was added to **FA 5** that had been heated. In the limewater test for carbon dioxide, candidates should state a positive result as showing both colour and state i.e. white precipitate/milky. Cloudy alone is not acceptable as this does not indicate specifically that the precipitate is white. If the question states that 'unknown' should be used where it has not been possible to positively identify an ion then candidates should feel secure in doing so.

(b) Since the anion was stated as being one of those listed on page 11 it was necessary to consider any of the halides, nitrate or nitrite. Most candidates chose to use the silver nitrate test and to test with aqueous sodium hydroxide to show the presence of nitrite or nitrate. Few recognised that in order to distinguish between these two, a mineral acid must be used. Better performing candidates provided a clear layout that showed the test, then observation and the conclusion.

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> **Paper 9701/36**
> **Advanced Practical Skills 2**

Key messages

- Candidates should recognise that the thermometer generally provided in enthalpy change exercises can be read to an accuracy of $\pm 0.5\,°C$.
- In exercises involving weighing, the term 'mass' is not synonymous with 'weight'.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.
- Candidates should be reminded to write their answers legibly in dark blue or black pen.
- Candidates should recognise that organic compounds can be included in those used in a Qualitative Analysis exercise.

Comments on specific questions

Question 1

(a) From the results obtained, the majority of candidates were able to carry out the practical successfully. Most candidates recorded their results in a suitable format. Better performing candidates recorded temperatures to $\pm 0.5\,°C$ and were careful to record the units of time correctly.

(b) In any graph, the scale chosen should result in the plotted points occupying more than half the available space on each axis. In this case, candidates were instructed to extend the scale on the y-axis to allow points up to $3\,°C$ higher than the maximum temperature obtained to be plotted. A significant number of candidates did not provide answers that matched these requirements.

(c) Most candidates were clearly aware of the use of energy = $mc\Delta T$ and the method for calculating the enthalpy change.

(d) Most candidates were able to calculate the percentage of zinc in **FB 2**.

Question 2

(a) The results were generally recorded in a satisfactory manner and the calculated percentage of mass lost on heating also showed that the practical exercise had been carried out satisfactorily.

(b) Some candidates confused the mass of water and the mass of anhydrous copper(II) sulfate in **(i)** and **(ii)**. The vast majority were clearly aware of the method needed to find the value of **x** in the formula of the hydrated salt. Answers that followed values in **(i)** and **(ii)** were accepted but **x** had to be given as an integer in **(iii).**

The equation in **(iv)** had to correspond to the value found in **(iii).**

(c) Candidates were expected to note the change in colour and some indication that heat had been released was required. An explanation of the significance of both these observations was needed.

(d) Better performing candidates gave the detail needed in this part. It was insufficient merely to say that if the value was less than the accepted value, then heating should be carried out for longer. Reference to the mass becoming constant was needed. It was also not worthy of credit to suggest that if the value was more than the accepted value, then this meant that the heating had been carried out for too long.

Question 3

When carrying out a test, candidates should be encouraged to think what observations were actually possible. This means that when using acidified potassium manganate(VII) it is necessary to observe whether or not the purple coloration is removed and in Tollens' test whether or not a silver mirror is formed.

(a) (i) Most candidates noted an effervescence and many suggested the use of limewater to identify the gas produced. It should be noted that for a positive test the observation should include both the colour and appearance of the product. It is insufficient therefore to say that the limewater goes cloudy; the colour white must also be specified.

(ii) A significant number of candidates correctly identified H^+ as the cation.

(iii) Some candidates gave an acceptable answer that was dependent on understanding the significance of the manganate(VII) or Tollens' test.

(iv) and **(v)**

In **(iv)** and **(v)** the higher temperature rise was linked to the difference in strength of the acids. Since the question stated that **FB 4** and **FB 5** were of equal concentration, answers based on concentration differences were not acceptable.

(b) It was evident that most candidates were familiar with the use of the Qualitative Analysis Notes. However, many did not realise that before the tests with aqueous sodium hydroxide and aqueous ammonia can be carried out it is necessary to make an aqueous solution of the unknown.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key Messages

Candidates are encouraged to read the questions carefully, ensuring their answers meet the requirements of each question. This helps avoid answers that use the wrong type of structure, or calculations that omit the + or – sign or with answers given to the wrong number of significant figures.

General Comments

The paper was found to be accessible to the majority of candidates. There were many satisfactory or good responses, and a significant number of very good and excellent ones. The overall performance on the calculations on this paper was of a good standard.

Comments on Specific Questions

Question 1

(a) $4s^2\ 3d^9$ was a very common incorrect answer for the copper atom.

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

(ii) The chloride complex was regularly incorrectly given as green.

(iii) This was answered well by many candidates.

(iv) This was answered well by many candidates. Some candidates made careless errors, such as ionic charges outside the final square brackets, which signify concentration.

(c)(i) Many candidates gave, 'a ligand that forms two bonds'; complete answers were rare.

(ii) Many candidates answered in terms of the relative stabilities of the complex ions, rather than the equilibrium positions.

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

(ii) Very many good answers were seen here. Candidates who performed well used clear and consistent 3–D bond conventions. Some diagrams incorrectly had individual *en*-ligands forming two covalent bonds with a 180° bond angle between them.

(e)(i) Many candidates knew that a Brønsted–Lowry base receives a proton but did not go on to give a full answer.

(ii) Although many correct answers were seen, overall this question was not well answered. Common errors included equations involving the protonation of one $-NH_2$ group only, and equations showing the formation of Cl_2 as a second product.

(f)(i) It was common to see a diagram showing two of each monomer joined together, beginning H_2N- and ending $-CO_2H$, rather than two of each monomer as part of a longer polymer chain, beginning $-HN-$ and ending $-CO-$.

(ii) This was answered well by many candidates.

(iii) This was answered well by many candidates, although some gave e.g. biodegradable polyesters or polyamides.

Question 2

(a) Many candidates correctly stated that a solid copper oxide residue would be observed. Observations on lime water going milky did not answer the question, as this is a further test and not an observation.

(b) A number of answers stated that the polarising power of the cation decreases, but did not state what is being polarised. In this case, it is the carbonate anion that is being polarised.

(c)(i) Many answers were seen that involved the wrong number of electrons and with atoms with more than eight outer electrons.

(ii) This was answered well by many candidates.

Question 3

(a) The majority of candidates' explanations were not detailed enough and many partly restated information given in the question. For example in **(i)**, a clear statement here that 'the number of gas molecules increases' would have been suitable.

(b)(i) Many candidates ignored the instruction to 'include a relevant sign'.

(ii) Some candidates did not make it clear as to what they were describing. $T\Delta S$ is a positive number, so it can be said to *increase* as T increases. However if candidates are talking about $-T\Delta S$ this is a negative number, so expressions like 'increase' or 'decrease' should not be used. Instead $-T\Delta S$ should be said to become *more negative* as T increases.

(c) This was answered well by many candidates.

(d) Many candidates described 'the reaction becoming more endothermic down the group'. This was not acceptable as dissolving is not a reaction. A reference to 'enthalpy change of solution becoming more endothermic (or less exothermic) down the group' was required.

Question 4

(a) Correct definitions were comparatively rare.

(b)(i) These species were not well known.

(ii) These colours were not well known.

(c) Many answers referred to either the standard hydrogen electrode or described the standard conditions, but very few included both.

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

(ii) This was answered well by many candidates. Some equations were seen in which both species were oxidised, or both were reduced.

(iii) This was answered well by many candidates.

(e)(i) A number of correct answers were seen.

(ii) This was answered well by many candidates.

(f) The correct answer was rarely seen. Many candidates realised the vanadium would be oxidised to V^{2+} or V^{3+} but did not go on to suggest it would be further oxidised by Fe^{3+}.

Question 5

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

(ii) This was answered well by many candidates.

(b) This was answered reasonably well by many. However a common mistake was to fill in the 'functional group' column with 'alcohol, carboxylic acid, ester'. It is not possible, having identified the molecular formula as $C_3H_6O_3$, for the molecule to have all three of these groups.

(c)(i) The term *relative peak area* was not well understood.

(ii) Many statements such as 'doublet because one neighbouring hydrogen' were seen. This was not enough, as it could mean one neighbouring hydrogen on the same carbon atom – a CH_2 group. Candidates who performed well specified 'doublet because the neighbouring carbon atom(s) have one hydrogen'. Some candidates incorrectly stated 'duplet'.

(iii) This was answered well by many candidates.

(iv) Many candidates gave the correct structure, although $CH_2OHCH_2CO_2H$ was also a common answer.

(d)(i) Correct answers were comparatively rare and many candidates drew the same structure twice.

(ii) Correct answers of 4 and 4 were very rare. The commonest answers were 2 and 2.

Question 6

(a) Many candidates noted the presence of a carboxylic acid and an amide but missed the presence of a phenol.

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

(ii) This was answered well by many candidates.

(c) This was not generally answered well. The commonest errors were to:
- reduce the $-CO_2H$ group in ibuprofen to an $-OH$ group rather than a $-CH_2OH$ group
- reduce the $C=O$ group in paracetamol to a CHOH group rather than a CH_2 group
- cleave the amide link in paracetamol.

(d)(i) Many candidates chose reagents with complicated reactions, such as 2,4-DNPH, making **(d)(ii)** and **(d)(iii)** much more difficult than was necessary.

(ii) Candidates who chose Na_2CO_3 in **(d)(i)** almost always answered this part correctly.

(iii) Candidates who chose Br_2 in **(d)(i)** almost always answered this part correctly.

(e)(i) CH_3CO^- was included in many wrong answers.

(ii) Many diagrams were drawn with care and precision. One of the commonest errors was to join the CH_3 group to the ring instead of the CO group. Sometimes the curly arrow in the last part of the mechanism was shown incorrectly coming from the hydrogen atom and not from the C–H bond.

(iii) This was answered well by many candidates.

Question 7

(a)   Many candidates correctly calculated the moles of thiosulfate and used this to calculate the moles of bleach in the flask. Fewer calculated the concentration of the undiluted bleach.

(b)(i)   Some candidates had performed this titration and therefore knew these practical details well.

(ii)   Candidates who had performed this titration knew the colour change from dark blue to colourless.

(iii)   These candidates also knew the time to add the starch being when the colour of the iodine had already become very pale. Other candidates chose an acid-base indicator in **(b)(i)** and struggled from there onwards.

(c)   This was answered well by many candidates.

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

(ii)   Candidates found this part challenging, with answers suggesting the value of K_c will change as concentrations change.

(iii)   This was answered well by many candidates.

(e)(i)   To explain how the buffer controls the pH when alkali is added many candidates gave the equation $OH^- + H_3O^+ \rightarrow 2H_2O$. This does not explain how this buffer system acts to control pH.

(ii)   This was answered well by many candidates.

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Key messages

The Question Paper requires answers to be written in dark blue or black ink; the use of pencils by candidates in writing formulae, structures and equations is to be strongly discouraged. Pencilled text is sometimes too faint to read. The practice of over-writing pencil in ink should be discouraged as answers often become illegible.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics.

There was no evidence of candidates being short of time.

Candidates need to show clear working in mathematical questions; where a final answer is incorrect, credit can often be obtained from correct working.

This report should be read in conjunction with the published mark scheme for this paper, which offers accepted answers to the questions.

Comments on specific questions

Question 1

(a)   This was generally well known. A common error was not linking transition element ions to having an incomplete d subshell.

(b) (i)   Co-ordination number was much better known than oxidation number.

   (ii)   This was well answered.

   (iii)   Candidates had to draw a four-co-ordinated structure of this complex and name its shape. Many candidates gave a correct structure but then gave the incorrect name.

(c) (i)   This was well answered by most candidates. Common errors were Cl_2 and PCl_5.

   (ii)   Many candidates gave the correct answer here.

(d) (i)   This was generally well known. A common error was optical isomerism.

   (ii)   A minority of candidates gave correct three-dimensional octahedral diagrams of the two isomers. The quality of diagrams was mixed and many did not use wedged and hatched bonds in the drawing of octahedral structures.

Question 2

(a)   Most candidates gave the correct answer here. A common error was $NaN_3 \rightarrow Na^+ + N_3^-$.

(b)   Some candidates gave the correct answer. Common errors were the central nitrogen atom having more than eight electrons and no dative bond shown.

(c) (i)   This was well answered. Common errors were omitting '1 mole' with ionic compound and 'gaseous' with ions.

(ii)   This was generally well known.

(iii)   Some candidates gave the correct answer but common incorrect responses included omission of 494, use of 944 or multiples of the other values.

(iv)   Many candidates answered this correctly.

Question 3

(a)   Most candidates answered this question well. The most common error was to form the ion by losing the 3d electrons before the 4s.

(b) (i)   Most candidates gave the correct answer here.

(ii)   This was generally well known. Several candidates either omitted the charges on the ions or gave incorrect charges.

(iii)   This was generally well known.

(iv)   Some candidates answered this question well, though some gave two unbalanced equations or two balanced equations but showing how $\underline{Fe^{2+}}$ ions can catalyse this reaction. Candidates should be encouraged to check they are answering the question as written.

(c) (i)   This was well answered. Common errors were omitting 'system' or 'substance'.

(ii)   Many candidates answered this correctly. Several also calculated the total entropy change.

(iii)   Some candidates gave the correct answer. Common incorrect responses included using incorrect equations or not dividing ΔS by 1000.

(iv)   Many candidates found this challenging. Some recognised that the rate would increase, but only the better performing candidates also linked to higher collision rate or more molecules possessing E_a.

Question 4

(a)   This was generally well known. Common incorrect responses included omission of d orbital splitting or mentioning d orbitals.

(b) (i)   This question proved challenging for most candidates. Common errors were incorrect products identified, for example CuO, $Cu(OH)_2$ and H_2.

(ii)   Common incorrect answers were 8.13 (candidates had not taken into account $250\,cm^3$) and 40.6 ($2:1\ S_2O_3^{2-}:Cu^{2+}$ ratio used).

Question 5

(a)   Most candidates answered this question well. The most common error was writing the K_c expression here.

(b)(i) Many candidates incorrectly thought that a buffer solution maintains pH or keeps pH constant. Some candidates didn't appreciate that only small amounts of acid or alkali are added.

(ii)   This question proved challenging for many candidates. Many gave equations showing how the $H_2PO_4^-$ and HPO_4^{2-} species can donate a proton or accept a proton from water but not when acting as a buffer.

(c)   This buffer calculation proved challenging for some candidates. A common incorrect response included reversing the $[HPO_4^{2-}]/[H_2PO_4^-]$ ratio.

(d)(i) This proved challenging for many candidates. A common error was using OH^- as a reactant here.

(ii)   This proved challenging for candidates. A common error was the incorrect ionic charge on the phosphate ion product as PO_4^-.

Question 6

(a)   Many candidates answered this question well however a number of candidates left this blank.

(b)(i) Candidates often omitted a reference to equilibrium.

(ii)   This calculation discriminated well and many fully correct answers were seen.

(c)   This was found to be a challenging question by many candidates. Common incorrect answers included:
   - omission of either 2,6-dibromination of the phenol or addition of Br_2 to the C=C bond
   - reduction of the C=C and C=O group of the ester with $NaBH_4$
   - omission of the sodium salt for the phenol and/or carboxylic acid in the two products with excess NaOH(aq).

(d)   This proved challenging for many candidates. The key point here was forming a mixture of optical isomers. Reference to purity alone was a common answer.

Question 7

(a)(i) Candidates generally knew the name of the mechanism here.

(ii)   This question discriminated well; a good number of fully correct answers were seen. Common incorrect responses included:
   - omission of the equation for the generation of the electrophile, Br^+
   - incorrect source or direction of the curly arrows
   - partial charges shown on the intermediate carbocation.

(b)   This proved challenging for many candidates. Often one amide was identified but an incorrect response was given for the other substance.

(c)(i) Step 4 was the most well-known, followed by 3, then 2 and least answered was step 1. Common errors were omitting $AlCl_3$ from step 1 and concentrated from step 3, or an incorrect name or formula for $KMnO_4$.

(ii)   This was well answered. Many diagrams were well drawn.

(d)(i) Many candidates answered this incorrectly. The most common error was reducing the C=O group to the C–OH group.

(ii)   Most candidates gave the correct answer here.

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(e) (i) CH$_3$COOH was often correctly identified. Only the better performing candidates suggested the other product would be the 4-bromophenylamine salt. Common errors were ethanoyl chloride and 4-bromophenylamine.

(ii) This was generally well answered. A common error was the acyl chloride.

(iii) This was found to be a very challenging question. Many candidates suggested there would be little/no hydrogen bonding to water. Only better performing candidates gave a reference to the structure of **X** in terms of being non-ionic or less polar.

Question 8

(a) Many candidates answered this correctly. Some candidates did not use all the information given and merely showed a calculation for the molecular mass.

(b) (i) Most candidates gave skeletal structures. A common error was drawing the 2-methylbutanoic acid structure in a different orientation.

(ii) Many candidates answered this question well. 3-methylbutanoic acid was a common error.

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

(ii) Most candidates correctly identified the hybridisation of the carbon atoms. Many candidates incorrectly identified the environment of the carbon atom for peaks at δ 27 and 41.

(d) (i) The type of proton was quite well known, but number of protons less so. The splitting pattern was quite well known but duplet was a common incorrect response.

(ii) This proved challenging for many candidates.

(e) Many candidates answered this incorrectly. The most common error was TMS.

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Key Messages

Candidates are encouraged to read the questions carefully, ensuring their answers meet the requirements of each question. This helps avoid answers that use the wrong type of structure, or calculations that omit the + or – sign or with answers given to the wrong number of significant figures.

General Comments

The paper was found to be accessible to the majority of candidates. There were many satisfactory or good responses, and a significant number of very good and excellent ones. The overall performance on the calculations on this paper was of a good standard.

Comments on Specific Questions

Question 1

(a) $4s^2\ 3d^9$ was a very common incorrect answer for the copper atom.

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

(ii)   The chloride complex was regularly incorrectly given as green.

(iii)   This was answered well by many candidates.

(iv)   This was answered well by many candidates. Some candidates made careless errors, such as ionic charges outside the final square brackets, which signify concentration.

(c)(i)   Many candidates gave, 'a ligand that forms two bonds'; complete answers were rare.

(ii)   Many candidates answered in terms of the relative stabilities of the complex ions, rather than the equilibrium positions.

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

(ii)   Very many good answers were seen here. Candidates who performed well used clear and consistent 3–D bond conventions. Some diagrams incorrectly had individual *en*-ligands forming two covalent bonds with a 180° bond angle between them.

(e)(i)   Many candidates knew that a Brønsted–Lowry base receives a proton but did not go on to give a full answer.

(ii)   Although many correct answers were seen, overall this question was not well answered. Common errors included equations involving the protonation of one $-NH_2$ group only, and equations showing the formation of Cl_2 as a second product.

(f)(i)   It was common to see a diagram showing two of each monomer joined together, beginning H_2N- and ending $-CO_2H$, rather than two of each monomer as part of a longer polymer chain, beginning $-HN-$ and ending $-CO-$.

(ii)   This was answered well by many candidates.

(iii) This was answered well by many candidates, although some gave e.g. biodegradable polyesters or polyamides.

Question 2

(a) Many candidates correctly stated that a solid copper oxide residue would be observed. Observations on lime water going milky did not answer the question, as this is a further test and not an observation.

(b) A number of answers stated that the polarising power of the cation decreases, but did not state what is being polarised. In this case, it is the carbonate anion that is being polarised.

(c)(i) Many answers were seen that involved the wrong number of electrons and with atoms with more than eight outer electrons.

(ii) This was answered well by many candidates.

Question 3

(a) The majority of candidates' explanations were not detailed enough and many partly restated information given in the question. For example in **(i)**, a clear statement here that 'the number of gas molecules increases' would have been suitable.

(b)(i) Many candidates ignored the instruction to 'include a relevant sign'.

(ii) Some candidates did not make it clear as to what they were describing. $T\Delta S$ is a positive number, so it can be said to *increase* as T increases. However if candidates are talking about $-T\Delta S$ this is a negative number, so expressions like 'increase' or 'decrease' should not be used. Instead $-T\Delta S$ should be said to become *more negative* as T increases.

(c) This was answered well by many candidates.

(d) Many candidates described 'the reaction becoming more endothermic down the group'. This was not acceptable as dissolving is not a reaction. A reference to 'enthalpy change of solution becoming more endothermic (or less exothermic) down the group' was required.

Question 4

(a) Correct definitions were comparatively rare.

(b)(i) These species were not well known.

(ii) These colours were not well known.

(c) Many answers referred to either the standard hydrogen electrode or described the standard conditions, but very few included both.

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

(ii) This was answered well by many candidates. Some equations were seen in which both species were oxidised, or both were reduced.

(iii) This was answered well by many candidates.

(e)(i) A number of correct answers were seen.

(ii) This was answered well by many candidates.

(f) The correct answer was rarely seen. Many candidates realised the vanadium would be oxidised to V^{2+} or V^{3+} but did not go on to suggest it would be further oxidised by Fe^{3+}.

Question 5

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

  (ii)   This was answered well by many candidates.

(b)   This was answered reasonably well by many. However a common mistake was to fill in the 'functional group' column with 'alcohol, carboxylic acid, ester'. It is not possible, having identified the molecular formula as $C_3H_6O_3$, for the molecule to have all three of these groups.

(c)(i)   The term *relative peak area* was not well understood.

  (ii)   Many statements such as 'doublet because one neighbouring hydrogen' were seen. This was not enough, as it could mean one neighbouring hydrogen on the same carbon atom – a CH_2 group. Candidates who performed well specified 'doublet because the neighbouring carbon atom(s) have one hydrogen'. Some candidates incorrectly stated 'duplet'.

  (iii)   This was answered well by many candidates.

  (iv)   Many candidates gave the correct structure, although $CH_2OHCH_2CO_2H$ was also a common answer.

(d)(i)   Correct answers were comparatively rare and many candidates drew the same structure twice.

  (ii)   Correct answers of 4 and 4 were very rare. The commonest answers were 2 and 2.

Question 6

(a)   Many candidates noted the presence of a carboxylic acid and an amide but missed the presence of a phenol.

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

  (ii)   This was answered well by many candidates.

(c)   This was not generally answered well. The commonest errors were to:
- reduce the $-CO_2H$ group in ibuprofen to an $-OH$ group rather than a $-CH_2OH$ group
- reduce the $C=O$ group in paracetamol to a CHOH group rather than a CH_2 group
- cleave the amide link in paracetamol.

(d)(i)   Many candidates chose reagents with complicated reactions, such as 2,4-DNPH, making **(d)(ii)** and **(d)(iii)** much more difficult than was necessary.

  (ii)   Candidates who chose Na_2CO_3 in **(d)(i)** almost always answered this part correctly.

  (iii)   Candidates who chose Br_2 in **(d)(i)** almost always answered this part correctly.

(e)(i) CH_3CO^- was included in many wrong answers.

  (ii)   Many diagrams were drawn with care and precision. One of the commonest errors was to join the CH_3 group to the ring instead of the CO group. Sometimes the curly arrow in the last part of the mechanism was shown incorrectly coming from the hydrogen atom and not from the C–H bond.

  (iii)   This was answered well by many candidates.

Question 7

(a) Many candidates correctly calculated the moles of thiosulfate and used this to calculate the moles of bleach in the flask. Fewer calculated the concentration of the undiluted bleach.

(b)(i) Some candidates had performed this titration and therefore knew these practical details well.

(ii) Candidates who had performed this titration knew the colour change from dark blue to colourless.

(iii) These candidates also knew the time to add the starch being when the colour of the iodine had already become very pale. Other candidates chose an acid-base indicator in **(b)(i)** and struggled from there onwards.

(c) This was answered well by many candidates.

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

(ii) Candidates found this part challenging, with answers suggesting the value of K_c will change as concentrations change.

(iii) This was answered well by many candidates.

(e)(i) To explain how the buffer controls the pH when alkali is added many candidates gave the equation $OH^- + H_3O^+ \rightarrow 2H_2O$. This does not explain how this buffer system acts to control pH.

(ii) This was answered well by many candidates.

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General comments

Nearly all the candidates correctly quoted their table calculations in **2(a)** to one decimal place in the first column and two decimal places in the second. In **1(c)(i)**, the required three significant figures were usually achieved with correct rounding and the negative sign given.

Incidences of overwriting, where the written responses or numbers are started in pencil then overwritten in ink with the pencil erased, were less prevalent this year. Overwriting can produce confused answers where it is difficult to read the candidate's response.

Candidates should be discouraged from providing multiple responses to a simple question, as this can lead to a contradiction within the answer. For example in **2(c)(ii)** two different calculations were seen with different answers, which contradicted each other. In **2(d)(i)**, contradictory list answers such as 'value read before 2000s' or 'timer was stopped early' or 'concentration was too high' were common.

Some candidates needed more practice in answering evaluative type questions such as those required for **Question 1(a)** and **2(d)**.

Comments on specific questions

Question 1

(a) This question required the candidates to understand the solubility data, in particular the insolubility of some of the silver and barium compounds. The penultimate paragraph in the introduction was designed to lead candidates into the identity of the red precipitate as being silver chromate(VI). Nevertheless, silver chloride or various barium compounds were given as the red precipitate. This may indicate that candidates did not properly study the provided information and as a result did not provide a good answer. Candidates are advised to read the entire question before answering the question parts.

    (i) A variety of responses were given including formulae, even though the question specifically asked for a name. Some candidates confused chromate with dichromate. The equation was not done well. A common response was $Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4$, which lacks the necessary 2 in front of the Ag^+.

    (ii) This question concerned the solubility of barium chromate being an order of magnitude less than that of silver chromate. Barium ions remove chromate ions from solution thus preventing them from reacting with silver ions to produce the red precipitate. Essential to a correct response was that the chromate ions are precipitated in the barium compound. They are no longer in solution and are not available to the silver ions, so they cannot act as an indicator. A significant number of candidates responded that the barium ions just reacted with chromate ions. Precipitation of chromate ions was central to the answer.

(iii)   Again, this question concerned the low solubility and thus the precipitation of barium sulfate. In order for the barium ions not to react with chromate ions, the barium ions need to be removed from solution. This removal is achieved by reaction with sulfate producing a precipitate; so precipitation was an essential part of the answer. Only stating that barium and sulfate ions react was insufficient. This part was more successfully answered than **1(a)(ii)**. Neither this question nor **1(a)(ii)** showed sufficient thought or consideration of the data in the majority of the candidates' responses.

(b)   The question asked for a sketch graph and this sketch has to be accurate to reflect the trend. In this question the requirement was for a straight upward sloping line from the origin followed by a second straight line parallel to the silver nitrate axis. The use of a ruler for straight lines is preferred. As both lines are straight then no curves at any point were accepted. Many candidates had curves in their plots. Labelling of the axes was well done. The volume of silver nitrate (the independent variable) had to be on the *x*-axis.

(c) (i)   This question was usually well answered. Some candidates provided more than three items. The volumes of the pieces were usually presented with a correct unit. The most common missed piece was a volumetric flask and the most common incorrect inclusion a conical flask.

(ii)   The making of a volumetric solution is a standard procedure, which should be well known. Better performing candidates described dissolving a known mass of solid in a beaker, transferring that solution to a volumetric flask and making the solution up to the mark with distilled water. Common errors were not stating the mass and dissolving directly into the volumetric flask. A number of candidates described how to make barium chloride from precursor chemicals and others added other chemicals such as sulfuric acid to the volumetric solution. Some seemed to be under the impression that the barium chloride described was a solution as they described transferring it to the volumetric flask by way of a pipette.

(iii)   Many candidates realised that it was a good idea to remove the barium ions before adding the indicator and that the silver nitrate titrant should be added last, leaving the chromate indicator in the middle. A number included barium nitrate in the list having not realised that the barium chloride was already present.

(iv)   The idea of concordancy was fairly well known and a number of terms such as consistent or constant were acceptable, as well as titres to $\pm\,0.1\,cm^3$. Unacceptable answers included '$\pm\,0.2\,cm^3$', '$\pm\,0.01\,cm^3$', 'accurate' and 'about the same'. Often 'repeat the experiment' or 'calculate a mean' were offered.

(v)   This calculation was often done well. There are many different calculation methods that all led to the same correct answer. Some errors were made in calculating M_r, particularly that of water. Most commonly, errors were made during the course of the calculation. Some candidates assumed that the value of **x** was 1, which rendered further calculation irrelevant. Only a small number of candidates gave a non-integer answer.

(d)   Candidates found this question challenging. Candidates were required to state a specific hazard, the chemical producing it and a relevant precaution. Better performing candidates stated that "potassium chromate(VI) causes skin irritation and use gloves.' Some responses did not attribute a hazard to a particular chemical, producing a list gleaned from the information when the question specifically asked for just one hazard or quoting health hazard that is non-specific. Hazards associated with silver nitrate were not accepted as the concentration used in the question was non-hazardous. Similarly the toxicity of barium chloride is limited to the solid state so referring to barium chloride solutions as toxic was not accepted.

Question 2

(a)   The majority of the candidates did well on this question. Most candidates calculated correctly from the data of α. The majority of candidates had the correct decimal places in both columns of answers.

(b)(i)   The data points were well plotted and there was hardly any inaccurate plotting. There were isolated examples of correct data being mis-plotted. Most candidates drew a good line.

(ii)   This was generally answered well. Most candidates either talked in terms of the line going through most points or that the straight line and the expression $y = mx + c$ confirmed the relationship of the equation in the question. Some referred to the gradient but did not mention that for a straight line the gradient had to be constant. A few suggested that the relationship was one of inverse proportionality. A negative gradient was also not allowed since negative could also apply to a curve.

(c)(i)   As the graph was plotted well, most candidates chose table points that were on the line to be the selected gradient co-ordinates. The use of table points was acceptable. Most candidates presented their co-ordinates in the correct x,y format. A few candidates selected co-ordinates that were too close together. Co-ordinates should be separated by at least half of the graph. The calculation from the co-ordinates was straight forward and was done well, with most candidates correctly quoting the gradient to three significant figures, including the trailing zeros, if necessary. Only a few candidates did not provide the negative.

(ii)   A significant minority of candidates managed to overcomplicate this calculation and progress into error. This may be that candidates did not realise that the given equation was of the form $y = mx + c$ so did not realise that the gradient calculated above, was m and equal to $-k/2.3$ Thus, all that was necessary was to multiply the calculated gradient by 2.3 and equating that to $-k$ and then k, ensuring that the two negatives were handled properly.

(d)(i)   Very few candidates performed well here. Typical incorrect answers were concerning temperature or concentration errors. Quite a number of candidates answered that the timer was stopped early or late, probably not realising that this was a single continuous experiment. This question was particularly prone to list answers, some of which were contradictory.

(ii)   It was apparent that a significant minority of candidates either did not understand what was meant by half-life or did not know how to work it out. Of those that did, the most popular co-ordinates were 0,42 and 680,21, giving a half-life of 680 seconds. There were other co-ordinates used, which were acceptable, provided the second y value was half of the first. A few candidates calculated two half-lives and took an average, which was good. Some candidates mis-read the y-axis, reading 44 and 22 instead of 42 and 21. A number of candidates tried to answer by finding a gradient at some point. This usually gave a negative value.

(iii)   Most candidates did well in this calculation. Quite a few used the 500 s value even though they had a value in the previous question.

(iv) The essence of this question was the comparison between the two *k* values previously calculated and stating that the one with the highest value would have been at the higher temperature. A few responses did not refer to *k* values or based their answers on reaction rates. There were a number of generalised statements such as 'a higher temperature produces higher values of *k*' but those do not include the essential comparison of two values.

(v) The lack of variation of half-life following a concentration change seemed well known but not well explained. An explanation 'half-life unchanged' was not sufficient. There was a requirement for half-life to be independent of concentration, or the reaction is first order. Some candidates wrote incorrect chemistry such as 'concentration has no effect on reaction rate'.

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Key messages

If a stated number of points in an answer is required, then candidates should not provide more. For example, **1(b)(i)** required the names (and sizes) of **three** (this was given in bold) pieces of volumetric apparatus needed in order to carry out a titration.

Candidates should make sure that they have understood the purpose of an experiment that is described in a question. Their answers should relate directly to the procedures and problems relevant to this experiment. This applied particularly to the practical based problems seen in questions **2(b)(ii)** and **2(c)(i)**.

It was noticeable that the standard of graph work had improved with many candidates achieving full credit for **2(a)(ii)** and **2(c)(ii)**.

General comments

Candidates answered the questions on this paper far more successfully than in recent sessions with strong responses seen to many theoretical and numerical parts, particularly those seen in **Question 2**. Some responses to the questions which looked at practical applications in **Question 1** were less strong however.

The more practical work that a candidate has carried out during their studies the more prepared and confident they will be in answering the questions on this paper.

Comments on specific questions

Question 1

(a)   This was answered correctly in terms of the formation of hydrogen ions by the majority of the candidates. Others attempted to define or explain the function of a buffer solution, (often incorrectly) which did not answer the question.

(b) (i)   Many candidates do not understand the term 'volumetric' and consequently beakers and conical flasks appeared frequently as answers.

Most candidates did manage to give two pieces of volumetric apparatus of a suitable volume, but often the third was a conical flask or a measuring cylinder. Those who ignored the instruction to name **three** (in bold) pieces of apparatus and listed more than three often did not receive full credit.

(ii)   Many candidates knew how to calculate an appropriate mass for a volume of solution but often chose an inappropriate volume. Occasionally rounding errors were seen with the (expected) answer (for a $250 \, cm^3$ volumetric flask) of $9.305 \, g$ being rounded to $9.30 \, g$.

(iii)   It was clear that many candidates had not come across the accepted procedure for preparing standard solutions from a solid.

The key points are:

using a relatively small volume of distilled water to dissolve the solid in a beaker
transferring this solution (with 'washings') into a volumetric flask and topping up to the ($250 \, cm^3$) mark with distilled water followed by (several) inversions to ensure a homogeneous solution.

Many candidates showed poor experimental technique by adding the weighed solid directly into the volumetric flask and then attempting to dissolve it.

Nearly all knew that the final volume had to be 'made up to the mark using water', but it is important to state that distilled (or de-ionised) water should be used in both steps.

(iv)(v)   In these two parts, many candidates confused accuracy and reliability and gave transposed responses.

The accuracy question, **(iv)**, required the EDTA solution to be added drop by drop or 'drop-wise' close to the rough end-point rather than 'carefully' or 'slowly'.

The reliability question, **(v)**, required candidates to state that two titres should be within $0.10 \, cm^3$ of each other. Candidates should be careful with their phrasing of answers to this question as answers such as 'repeat until all titres are within $0.10 \, cm^3$ of each other' were not given credit. In general, the concept of concordant titres seems well understood and 'within $0.10 \, cm^3$' was often seen. However, there were a significant minority who suggested simply averaging titres.

(c) (i)   Most candidates could identify a hazard and suggest a suitable precaution, commonly either 'corrosive' and 'wear gloves' or 'flammable' and 'avoid naked flames'. However, some candidates did not realise that the hazard was, for example, 'corrosive' and instead named sodium hydroxide as the hazard.

Candidates should be careful to only provide the required number of responses. Some gave two sets of hazards and precautions, often providing an erroneous response alongside a correct one, and thus credit could not be awarded.

(ii)   This calculation differentiated very well amongst the stronger candidates. One way through this calculation was as follows:
Titre 1 led to the combined number of moles of EDTA reacting with Ca^{2+} and with Mg^{2+}. Titre 2 led to the number of moles of EDTA reacting with Ca^{2+}.
A subtraction of titre 2 from titre 1 led to the number of moles of EDTA reacting with Mg^{2+}.
The moles of Ca^{2+} and Mg^{2+} present in $25.0 \, cm^3$ of solution could therefore be calculated using a $1:1$ stoichiometric relationship.
This in turn allowed candidates to determine the concentrations of Ca^{2+} and Mg^{2+}.

There were many alternative variations of this method which would have produced the correct answers.

The most common error was to assume a $1:2$ stoichiometric relationship between EDTA and each of the metal ions.

Question 2

(a) (i) Most candidates were able to complete the table without errors in subtraction.

(ii) Nearly all candidates went on to plot the points correctly and make a good attempt at a line of best fit.

(iii) Most candidates could also explain that the results were reliable because 'the line of best fit went through most of the points'. However, the response 'because the points produced a smooth curve' was not an acceptable answer.

(iv) A significant proportion of candidates were unfamiliar with the concept of a half-life.

Of those who knew how to determine a half-life, many were unable to give two correct sets of co-ordinates but working shown on the graph (such as construction lines) enabled partial credit to be given where such working was sound.

(b) (i) Nearly all candidates achieved full credit for drawing an air-tight system consisting of a stoppered test tube leading to a suitable means of collecting and measuring the volume of the gas evolved; the vast majority opted to collect the gas in a gas syringe. Diagrams were generally well labelled.

(ii) This question tested the candidate's understanding of the procedural issues of the experiment, however, many spurious suggestions such as 'escape of gas' were seen as the reason. A significant proportion of candidates suggested that the percentage error in timing would increase. This indicated that these candidates had not appreciated that the experiment's procedure was one involving continual measurement rather than many separate timings.

Most were able to work out that $V_{final} - V$ would become smaller as a result of V becoming larger.

(c) (i) Only a few candidates were able to work out that the anomaly was caused simply by the volume of gas being recorded at a time later than 450 seconds. Once again many answers suggested that candidates did not appreciate the procedure of the experiment.

(ii) Most tangents were well drawn and their gradients calculated correctly from correctly read co-ordinates and many candidates gained full credit. The one common error which prevented many candidates gaining full credit was to not have a long enough tangent when it came to calculating its gradient. It was expected that candidates would make full use of the graph paper and consequently the y co-ordinates would be at least $100 \, cm^3$ apart.

(iii) Many candidates were able to use the data within the table to deduce that the reaction was first order. A variety of methods of calculating this order were used: some simply considered half-lives others used logarithms. Usually the calculation was clearly set out.

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>
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General comments

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Comments on specific questions

Question 1

(a)   This question required the candidates to understand the solubility data, in particular the insolubility of some of the silver and barium compounds. The penultimate paragraph in the introduction was designed to lead candidates into the identity of the red precipitate as being silver chromate(VI). Nevertheless, silver chloride or various barium compounds were given as the red precipitate. This may indicate that candidates did not properly study the provided information and as a result did not provide a good answer. Candidates are advised to read the entire question before answering the question parts.

   (i)   A variety of responses were given including formulae, even though the question specifically asked for a name. Some candidates confused chromate with dichromate. The equation was not done well. A common response was $Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4$, which lacks the necessary 2 in front of the Ag^+.

   (ii)   This question concerned the solubility of barium chromate being an order of magnitude less than that of silver chromate. Barium ions remove chromate ions from solution thus preventing them from reacting with silver ions to produce the red precipitate. Essential to a correct response was that the chromate ions are precipitated in the barium compound. They are no longer in solution and are not available to the silver ions, so they cannot act as an indicator. A significant number of candidates responded that the barium ions just reacted with chromate ions. Precipitation of chromate ions was central to the answer.

(iii) Again, this question concerned the low solubility and thus the precipitation of barium sulfate. In order for the barium ions not to react with chromate ions, the barium ions need to be removed from solution. This removal is achieved by reaction with sulfate producing a precipitate; so precipitation was an essential part of the answer. Only stating that barium and sulfate ions react was insufficient. This part was more successfully answered than **1(a)(ii)**. Neither this question nor **1(a)(ii)** showed sufficient thought or consideration of the data in the majority of the candidates' responses.

(b) The question asked for a sketch graph and this sketch has to be accurate to reflect the trend. In this question the requirement was for a straight upward sloping line from the origin followed by a second straight line parallel to the silver nitrate axis. The use of a ruler for straight lines is preferred. As both lines are straight then no curves at any point were accepted. Many candidates had curves in their plots. Labelling of the axes was well done. The volume of silver nitrate (the independent variable) had to be on the *x*-axis.

(c) (i) This question was usually well answered. Some candidates provided more than three items. The volumes of the pieces were usually presented with a correct unit. The most common missed piece was a volumetric flask and the most common incorrect inclusion a conical flask.

(ii) The making of a volumetric solution is a standard procedure, which should be well known. Better performing candidates described dissolving a known mass of solid in a beaker, transferring that solution to a volumetric flask and making the solution up to the mark with distilled water. Common errors were not stating the mass and dissolving directly into the volumetric flask. A number of candidates described how to make barium chloride from precursor chemicals and others added other chemicals such as sulfuric acid to the volumetric solution. Some seemed to be under the impression that the barium chloride described was a solution as they described transferring it to the volumetric flask by way of a pipette.

(iii) Many candidates realised that it was a good idea to remove the barium ions before adding the indicator and that the silver nitrate titrant should be added last, leaving the chromate indicator in the middle. A number included barium nitrate in the list having not realised that the barium chloride was already present.

(iv) The idea of concordancy was fairly well known and a number of terms such as consistent or constant were acceptable, as well as titres to $\pm\,0.1\,\mathrm{cm^3}$. Unacceptable answers included '$\pm\,0.2\,\mathrm{cm^3}$', '$\pm\,0.01\,\mathrm{cm^3}$,' 'accurate' and 'about the same'. Often 'repeat the experiment' or 'calculate a mean' were offered.

(v) This calculation was often done well. There are many different calculation methods that all led to the same correct answer. Some errors were made in calculating M_r, particularly that of water. Most commonly, errors were made during the course of the calculation. Some candidates assumed that the value of **x** was 1, which rendered further calculation irrelevant. Only a small number of candidates gave a non-integer answer.

(d) Candidates found this question challenging. Candidates were required to state a specific hazard, the chemical producing it and a relevant precaution. Better performing candidates stated that "potassium chromate(VI) causes skin irritation and use gloves.' Some responses did not attribute a hazard to a particular chemical, producing a list gleaned from the information when the question specifically asked for just one hazard or quoting health hazard that is non-specific. Hazards associated with silver nitrate were not accepted as the concentration used in the question was non-hazardous. Similarly the toxicity of barium chloride is limited to the solid state so referring to barium chloride solutions as toxic was not accepted.

Question 2

(a)   The majority of the candidates did well on this question. Most candidates calculated correctly from the data of α. The majority of candidates had the correct decimal places in both columns of answers.

(b) (i)   The data points were well plotted and there was hardly any inaccurate plotting. There were isolated examples of correct data being mis-plotted. Most candidates drew a good line.

(ii)   This was generally answered well. Most candidates either talked in terms of the line going through most points or that the straight line and the expression y = mx + c confirmed the relationship of the equation in the question. Some referred to the gradient but did not mention that for a straight line the gradient had to be constant. A few suggested that the relationship was one of inverse proportionality. A negative gradient was also not allowed since negative could also apply to a curve.

(c) (i)   As the graph was plotted well, most candidates chose table points that were on the line to be the selected gradient co-ordinates. The use of table points was acceptable. Most candidates presented their co-ordinates in the correct x,y format. A few candidates selected co-ordinates that were too close together. Co-ordinates should be separated by at least half of the graph. The calculation from the co-ordinates was straight forward and was done well, with most candidates correctly quoting the gradient to three significant figures, including the trailing zeros, if necessary. Only a few candidates did not provide the negative.

(ii)   A significant minority of candidates managed to overcomplicate this calculation and progress into error. This may be that candidates did not realise that the given equation was of the form y = mx + c so did not realise that the gradient calculated above, was m and equal to $-k$/2.3 Thus, all that was necessary was to multiply the calculated gradient by 2.3 and equating that to $-k$ and then k, ensuring that the two negatives were handled properly.

(d) (i)   Very few candidates performed well here. Typical incorrect answers were concerning temperature or concentration errors. Quite a number of candidates answered that the timer was stopped early or late, probably not realising that this was a single continuous experiment. This question was particularly prone to list answers, some of which were contradictory.

(ii)   It was apparent that a significant minority of candidates either did not understand what was meant by half-life or did not know how to work it out. Of those that did, the most popular co-ordinates were 0,42 and 680,21, giving a half-life of 680 seconds. There were other co-ordinates used, which were acceptable, provided the second y value was half of the first. A few candidates calculated two half-lives and took an average, which was good. Some candidates mis-read the y-axis, reading 44 and 22 instead of 42 and 21. A number of candidates tried to answer by finding a gradient at some point. This usually gave a negative value.

(iii)   Most candidates did well in this calculation. Quite a few used the 500 s value even though they had a value in the previous question.

(iv) The essence of this question was the comparison between the two *k* values previously calculated and stating that the one with the highest value would have been at the higher temperature. A few responses did not refer to *k* values or based their answers on reaction rates. There were a number of generalised statements such as 'a higher temperature produces higher values of *k*' but those do not include the essential comparison of two values.

(v) The lack of variation of half-life following a concentration change seemed well known but not well explained. An explanation 'half-life unchanged' was not sufficient. There was a requirement for half-life to be independent of concentration, or the reaction is first order. Some candidates wrote incorrect chemistry such as 'concentration has no effect on reaction rate'.