

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

The majority of candidates were able to finish the paper within the hour allowed.

Candidates found **Questions 1, 5, 6, 7, 8, 10, 11, 12, 16, 31, 32, 35** and **36** relatively easy. **Questions 9, 22, 24** and **40** were found to be more challenging.

Comments on specific questions

Question 9

The most commonly chosen incorrect answer was option **A**. If the numbers from option **A** are applied to the equation, there would be no electric charge on the left and a 1– charge on the right. This is not balanced for charge. On inspection, the oxidation number of chlorine increases by two and the oxidation number of manganese decreases by three. Therefore, three ClO_3^- ions are oxidised by two MnO_4^- ions, hence the answer **D**.

Question 22

Option **A** was a common incorrect choice. The position of the $\text{C}=\text{O}$ group and the COOH group show that the original compound must have included a five-membered ring; this rules out options **A** and **B**. If the answer were option **C**, the product would be $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{COOH}$; the methyl side chain is therefore in the wrong place. Option **D** gives the correct structure in the question.

Question 24

The most commonly chosen incorrect answer was option **D**. These candidates knew the mechanism to be nucleophilic substitution but thought that chloroethane will hydrolyse more rapidly than bromoethane. The $\text{C}-\text{Br}$ bond is longer and therefore weaker than the $\text{C}-\text{Cl}$ bond, this can also be verified using the data booklet. Since the $\text{C}-\text{Br}$ bond is weaker bromoethane is hydrolysed more rapidly than chloroethane, therefore the correct answer is option **B**.

Question 40

Option **C** was a common incorrect choice. To select the correct option, each compound had to be looked at separately.

- Compound 1 produces CH_3COOH , $\text{CH}_2\text{OHCH}_2\text{COOH}$ and CH_3OH .
- Compound 2 produces CH_3OH and $\text{HOOCCH}(\text{CH}_3)\text{CH}_2\text{COOH}$.
- Compound 3 produces $\text{CH}_2\text{OHCH}(\text{CH}_2\text{OH})\text{CH}_2\text{CH}_2\text{COOH}$ and CH_3COOH .

Compound 1 is therefore the only compound to produce three different organic products when hydrolysed. Hence, option **D** is the correct response.

The products from each compound are those formed by hydrolysis with water or hot $\text{HCl}(\text{aq})$. If hot $\text{NaOH}(\text{aq})$ is used, the sodium salts of the acids would be obtained, but the same number of products would be formed in each case.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

The majority of candidates were able to finish the paper within the hour allowed.

Candidates found **Questions 3, 4, 5, 6, 9, 10, 13, 15, 16, 18, 21, 24, 28** and **37** relatively easy. **Questions 2, 11, 20, 29, 32** and **38** were found to be more challenging.

Question 2

The most commonly chosen incorrect answer was option **C**. To produce 800 cm³ of 0.100 mol dm⁻³ solution requires 0.08 moles of the specified substance. Since the *M_r* of (NH₄)₂CO₃·H₂O is 114, this appears to be 9.12 g. However, the question says the solution must be a 0.100 mol dm⁻³ solution of NH₄⁺ ions. Since there are two NH₄⁺ ions in each formula unit of (NH₄)₂CO₃·H₂O, the mass needed is stated in option **A** 4.56 g.

Question 11

Option **A** was a common incorrect choice. Option **A** cannot be correct since by definition a conjugate acid-base pair differs only by a single H⁺ ion. Option **C** is correct because if OH⁻(aq) is added it will react with H₃O⁺ ions. This will cause the equilibrium to move to the right.

Question 20

The most commonly chosen incorrect answer was option **B**. Candidates choosing this option did not determine two of the six possible isomers. The correct response is option **D**. The structures of these isomers are:

- pent-1-ene
- cis pent-2-ene
- trans pent-2-ene
- 2-methyl but-1-ene
- 2-methyl but-2-ene
- 3-methyl but-1-ene.

Question 29

Option **D** was a common incorrect choice. The empirical formulae of the products of acid hydrolysis of each of the options are:

- A** CH₂O and CH₃O
- B** CH₂O and CH₂O
- C** C₃H₆O₂ and C₃H₈O
- D** is not hydrolysed.

Therefore, option **B** is the compound that gives two products with the same empirical formula.

Question 32

The most commonly chosen incorrect answer was option **C**. Candidates were confident that statements 2 and 3 are correct, but were not as certain about statement 1. Statement 1 is true; there are three bonds between the two atoms so the ten valence electrons are arranged as :C≡O: and there are two lone pairs in one molecule.

Question 38

Option **A** was a common incorrect choice. Candidates were confident that statements 1 and 2 are correct, but were not as certain about statement 3. If bromoethane reacts with ethanolic KCN, the organic product is propanenitrile, not ethanenitrile, so statement 3 is incorrect.

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Paper 9701/13
Multiple Choice

<i>Question Number</i>	<i>Key</i>	<i>Question Number</i>	<i>Key</i>
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12	A	32	D
13	D	33	B
14	B	34	B
15	B	35	C
16	C	36	D
17	A	37	B
18	A	38	B
19	D	39	A
20	A	40	D

General comments

A minority of candidates may have been unable to finish the paper within the hour allowed.

Candidates found **Questions 1, 5, 6, 7, 8, 11, 12, 13, 15, 16, 19, 21, 31, 32, 35** and **36** relatively easy. **Questions 2, 9, 34, 38, 39** and **40** were found to be more challenging.

Comments on specific questions

Question 2

The most commonly chosen incorrect answer was option **B**. These candidates did not realise that since 6.02×10^{23} carbon atoms is one mole of carbon, it will have a mass of 12.0g. One carat is 0.200g, therefore, 12.0g is 60 carats.

Question 9

Option **A** was a commonly chosen incorrect answer. If the numbers from option **A** are applied to the equation, there would be no electric charge on the left and a 1– charge on the right. This is not balanced for charge. On inspection, the oxidation number of chlorine increases by two and the oxidation number of manganese decreases by three. Therefore, three ClO_3^- ions are oxidised by two MnO_4^- ions, hence the answer **D**.

Question 34

Options **C** and **D** were common incorrect answers. Statement 1 is correct because a lower pressure will cause the rate of a gas-phase reaction to decrease. Statement 2 is correct as a less effective catalyst will also lower the reaction rate. Statement 3 is incorrect; if **S** is removed, the back reaction will slow down and so the net rate of formation of **R** will increase.

Question 38

The most commonly chosen incorrect answer was option **A**. Dehydration will produce two different alkenes from compound 3. The **OH** group drawn on the upper right of the structure can cause dehydration across the bond to its left, or across the bond beneath it.

Question 39

The most commonly chosen incorrect option was **B**. The majority of candidates were confident that statements 1 and 2 were true, but were less certain about statement 3. The intermediate here is $(\text{CH}_3)_2\text{C}(\text{CN})\text{O}^-$. This receives a proton to form the final product $(\text{CH}_3)_2\text{C}(\text{CN})\text{OH}$. It therefore behaves as a base and statement 3 is true.

Question 40

Option **C** was a common incorrect choice. To select the correct option, each compound had to be looked at separately.

- Compound 1 produces CH_3COOH , $\text{CH}_2\text{OHCH}_2\text{COOH}$ and CH_3OH .
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Compound 1 is therefore the only compound to produce three different organic products when hydrolysed. Hence, option **D** is the correct response.

The products from each compound are those formed by hydrolysis with water or hot $\text{HCl}(\text{aq})$. If hot $\text{NaOH}(\text{aq})$ is used, the sodium salts of the acids would be obtained, but the same number of products would be formed in each case.

CHEMISTRY

Paper 9701/21
AS Structured Questions

Key messages

- The importance of basic mathematical skills to successfully study chemistry cannot be over emphasised. There were many instances when the lack of simple mathematical techniques led to errors and consequently the loss of valuable marks.
- When questions require a single answer, there appears to be a trend for candidates to offer more than one response. This can lead to a contradiction or errors resulting in the loss of credit.
- Observations should include something that is seen, heard or noticed.
- Candidates should avoid vague references to 'it' in their responses, as it is not always clear what the 'it' refers to.

General comments

Practical related topics requiring answers to include observations appeared to present problems for many candidates.

The concept of the boiling of giant covalent or simple molecular compounds was challenging for many candidates.

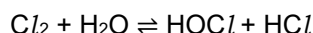
Mechanisms caused many candidates problems; a curly arrow represents the movement of two electrons, either from the middle of a covalent bond or from a lone pair of electrons, to the recipient atom. Many mechanisms showed curly arrows either coming from an atom or from a point well away from the lone pair of electrons.

Comments on specific questions

Question 1

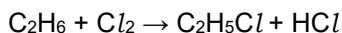
- (a) (i) The oxidising action of MnO_2 was often correctly answered by referring to the change in oxidation number of Mn (in MnO_2) from +4 to +2 (in MnCl_2). In a few instances, the change in oxidation number of Cl (in HCl) from -1 to 0 (in Cl_2) was also correctly given. A few answers non-specifically referred to the change in oxidation number of MnO_2 or just 'it' and were not creditworthy.
- (ii) The correct observations for the reaction between MnO_2 and HCl include 'effervescence', a 'green/yellow-green gas' and the 'solid dissolves'. Many answers referred to 'it' dissolves or ' MnO_2 ' dissolves, neither of which is an actual observation.
- (b) The trend in volatility of the Group 17 elements, $\text{Cl}_2(\text{g})$, $\text{Br}_2(\text{l})$ and $\text{I}_2(\text{s})$, was well answered. On a number of occasions 'volatility' was confused with 'boiling point'. Explanation of the decrease in volatility down the Group required mention of the increase in the strength of a specific intermolecular force, *induced dipoles*, as a result of an increase in the number of electrons.
- (c) (i) Answers explaining that chlorine undergoes disproportionation by being both oxidised and reduced in the same reaction were generally good. Equations to support the explanations were confused on occasions, with both HCl and HClO appearing as products for a reaction between NaOH and Cl_2 .
- (ii) Hot aqueous NaOH reacts with chlorine to form NaClO_3 , sodium chlorate(V); this question was generally well answered.

- (d) Chlorine is used as a disinfectant and added to water supplies to 'kill' pathogens, which is attributed to the action of HOCl , in acid solution:



Many answers correctly identified that the chlorine is added to water supplies, to 'kill' the pathogens; fewer correctly identified that the HOCl was the species responsible for this activity.

- (e) (i) The use of UV light to initiate the free-radical substitution reaction was widely known.
(ii) The **overall** equation for the reaction of chlorine with ethane was poorly answered.



Several answers started with CH_4 and contained a free radical in the equation or omitted HCl as a product.

Question 2

- (a) The bonding in some of the oxides of Period 3 elements was generally correct but the structure of each of the oxides was less well answered. Each of the ionic lattices Na_2O , MgO and Al_2O_3 , together with SiO_2 are described as giant structures, whereas SO_2 is molecular.
- (b) (i) The different boiling points of SiO_2 and SO_3 are associated with the difference in energy required to break the many actual covalent bonds, in SiO_2 , compared to the much weaker intermolecular forces of attraction, (IMFs), between the SO_3 molecules. Many candidates struggled with the concept of boiling and referred to weaker bonds in SO_3 compared to SiO_2 , whereas a quick check of bond energies in the *Data Booklet*, would have revealed that the difference between the bond energies for Si-O and S-O, is a mere 100 kJ mol^{-1} . SiO_2 has a large number of covalent bonds which are broken when it boils, but SO_3 has only comparatively very weak IMFs and thus the large difference in energy required to break many covalent bonds compared to weak intermolecular was lacking in many answers.
- (ii) The amphoteric nature of Al_2O_3 was well understood and the balanced equation for its reaction with an acid was well answered. However, the reaction of Al_2O_3 with an alkali was less well known, with many unbalanced equations because of the omission of H_2O from the reactant side of the equation.
- (iii) Observations when chemicals are mixed often proves challenging; in this instance many candidates gave answers consistent with adding sodium to water and not the oxide of sodium and water. When the solid, (Na_2O), is added to water, the solid dissolves to form a colourless solution.
- (c) (i) The octahedral shape of SeF_6 was well known.
- (ii) Candidates who appreciated that this enthalpy calculation involved the breaking of one $\text{Se}=\text{O}$ bond and the forming of two $\text{Se}-\text{O}$ bonds, in the polymeric reaction, tended to be awarded both marks.
- (iii) Several candidates misread the question and used SO_2 , instead of SeO_2 and many more candidates incorrectly gave H_2 and Na_2SeO_4 as products.

Question 3

- (a) (i) The process of breaking down long-chain hydrocarbons into shorter-chain hydrocarbons is called cracking. Many correct answers were seen.
- (ii) Low molecular mass hydrocarbons are used as fuels because they release a large amount of energy, burn cleanly and combust easily. Many responses focused on the 'volatility', low activation energy and aspects of pollution of the fuels, rather than appreciating that fuels are substances that are used to provide heat or power.

- (iii) Many candidates were awarded credit for correctly giving balanced equations showing the incomplete combustion of butane to form carbon monoxide as one of the products.
- (iv) The majority of responses were not creditworthy. Many described the use of either a 'catalytic converter', to calculate the amount of CO in the atmosphere, or fractional distillation of air to separate the CO. Infrared spectroscopy is frequently used to detect and monitor the levels of CO in the atmosphere by observing the level of the characteristic peak for the CO absorption.
- (b) (i) During reactions involving complete combustion the elements in a compound are burned and the products are primarily the most common oxides. The products from the complete combustion of thiophene, $C_4H_4S(l)$, are carbon dioxide, water and sulfur dioxide. Many answers gave the correct products and state symbols; the most common errors included stating sulfur, S, as a product and gas, (g), as a state symbol for water.
- (ii) Several definitions of the *enthalpy change of combustion* incorrectly stated that it was the 'energy/enthalpy required' for the combustion reaction. The key points of 'one mole of substance' and 'excess oxygen' were frequently missing.
- (iii) The majority of answers for the heat energy released when a certain mass of thiophene is combusted were correct. The most common errors included using 0.2 g, instead of 200 g, for the mass of water and adding 273 to the temperature change.
- (iv) The majority of answers correctly calculated the enthalpy change of combustion by dividing the heat energy released by the moles of thiophene. However, many candidates did not appreciate that if the temperature increased during the combustion, then the enthalpy change must be accompanied by a negative sign (-).

Question 4

- (a) (i) The naming of $(CH_3)_3CCHO$, was challenging for the majority of candidates. The longest chain contains three carbon atoms, one of which is contained within an aldehyde group, and two methyl groups are attached to the number 2 carbon atom. The name is thus 2,2-dimethylpropanal. The common errors were to omit the second 2, in 2,2- and the prefix 'di' when referring to the two methyl groups, on the second C atom.
- (ii) When candidates understood what is meant by the term *hybridisation*, this question was well answered. The most common error was mention of sp^3 , instead of the correct answer of sp^2 .
- (b) (i) The common reagent and conditions for an oxidation reaction involving an aldehyde group, is acidified potassium dichromate(VI) and heating under reflux. This question was well answered but some responses omitted 'acidified' or 'heat'.
- (ii) This question directed the candidates towards the use of intermolecular forces, (IMFs), in their answers. It required them to identify hydrogen bonds as the principal IMF in the solid carboxylic acid, **A**, $(CH_3)_3CCO_2H$ and dipole-dipole forces, in the liquid ester, **B**, $CH_3CO_2(CH_2)_2CH_3$. They needed to appreciate that H-bonding is the stronger IMF and will contribute to a compound being solid rather than a liquid. Several responses focused on the effect of branching, whilst others concentrated on chain length and surface contact, instead of identifying the different type of IMF in each compound.
- (iii) The equation for the reduction of $(CH_3)_3CCHO$ using $NaBH_4$ as the reducing agent, proved challenging for many candidates. Some answers contained $NaBH_4$ as a reactant, whereas the question directed the use of $[H]$ to represent the reducing agent. Other answers did not use $2[H]$, as a reactant and/or missed a C atom in the product.
- (iv) Many candidates recognised that the reaction of **A**, $(CH_3)_3CCO_2H$, with **T** involved an esterification reaction and correctly identified **T** as propan-2-ol, $(CH_3)_2CHOH$, using a catalyst, conc. H_2SO_4 or conc. H_3PO_4 .
- (c) (i) The majority of answers correctly stated that orange/red/yellow precipitates are observed when 2,4-DNPH is reacted separately with **X** and **Y**.

- (ii) The assigning of an aldehyde functional to the positive test with Fehling's solution was well answered. The most common incorrect answer was carbonyl or C=O.
- (iii) The definition of the term *chiral centre* was quite well answered. The most common errors were omitting that the four different groups/atoms are bonded/attached to a carbon atom and also referring to four different groups as 'molecules/compounds or ions'.
- (iv) Incorrect 3-D diagrams for the optical isomers of **Y** were quite common. Some structures contained three CH₃ groups, two linear solid bonds at 180° to each other or four different representations of covalent bonds.
- (v) This was a well answered question, with the majority of candidates stating the correct bonds for all three absorptions.
- (vi) Many answers gained credit for correctly drawing a skeletal representation of an alkene, **Z**, containing a C5 structure and an alcohol group. The question stated that **Z** was branched and showed *geometrical isomerism*; many candidates either did not note these requirements or were not aware of the criteria for a compound to exhibit geometric isomers. Many structures were either straight chain or contained two terminal methyl groups.
- (vii) This mechanism was generally poorly answered. The structure of **X**, (C₂H₅)₂C=O, with the correct polarity on the C=O group was the most common mark credited. Many candidates incorrectly showed arrows originating from the C atom, of the C=O group, rather than the middle of the π bond, or arrows not specifically from a lone pair of electrons. Many intermediate structures correctly showed a negative charge on the O atom, but there was no CN group bonded to the C, of the original C=O group.
- (viii) The catalytic role of the presence of a small amount of NaCN in this reaction was generally well recognised.

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key messages

- A good and detailed knowledge of all areas of the syllabus and the ability to apply relevant knowledge to different situations are essential in order to perform well.

General comments

Excellent responses were seen in answers to all items on this paper. The best responses used specific and appropriate vocabulary within the correct context. Weaker responses used specific vocabulary in a less precise manner and produced ambiguous answers.

There were some question items which candidates found demanding, for example **Questions 1(b)(i), 4(b) and 4(e)(iv)**; even so, there were candidates able to apply their knowledge to these novel situations in an accurate and detailed manner. In these items, better performing candidates made use of the details provided in the question stem.

In general, candidates performed less well when attempting organic chemistry questions.

Comments on specific questions

Question 1

- (a) (i) The shape of a p orbital as two equal sized lobes was well known; many correct diagrams were seen. Weaker responses drew shapes that showed a circle in the centre of the two lobes. In the absence of an indicated label or axis it was not possible to ascertain if the circle represented the origin of an axis or a region of volume between the two lobes, where there was a chance of finding an electron. Occasionally, three p orbitals were shown rather than one.
- (ii) Detailed equations describing the first ionisation energy of silicon with appropriate symbols were seen. Some responses showed equations with no or incorrect state symbols or showed the process with the arrow representing a reaction in equilibrium. Confusion was seen in equations that produced negatively charged ions or added an electron to a silicon atom to form a positive ion.
- (iii) Relevant details that explained the general increase in ionisation energy across Period 3 were well known and some very thorough explanations were seen. Some answers were incomplete; often omitting any reference to shielding effect.
- (iv) Many answers showed correct interpretation of the graph, deduced that **A** was a Group 13 element and explained their reasoning clearly. Many responses that assigned **A** to the wrong group were able to provide answers that appreciated that the *significant increase in ionisation energy after the third electron was removed* was key to deducing to which group element **A** belonged.
- (b) (i) This calculation was demanding; many answers were seen that used all the information provided to calculate the relative abundance isotope silicon-30. Weaker responses produced a general equation to represent the relationship between relative atomic mass and the abundance of the three isotopes but struggled to use the relationship between the total abundance of silicon-29 and silicon-30. The weakest answers attempted to make this calculation with no reference to the relative atomic mass of silicon.

- (ii) The majority of candidates deduced that the structure and bonding of silicon nitride was *giant and covalent*. Excellent responses were seen that used all the information given to explain their reasoning; others lacked appropriate detail. A common misconception described the forces holding the giant structure together as strong intermolecular forces. The idea of the structure lacking mobile charge carriers when molten was often ignored.
- (c) (i) In many cases, the products of combustion of C_2H_5SH were deduced correctly. Occasionally, sulfur or hydrogen sulfide was described as a product. Some equations were not balanced or were incorrectly balanced.
- (ii) A description of the formation of acid rain as an environmental consequence for the release of sulfur dioxide into the atmosphere was well known, as was a description of the effect of acid rain on the environment. Some answers correctly described the process involved to make acid rain from sulfur dioxide emissions; this was not a requirement of the question.
- (d) (i) Good responses appreciated that there would be no change in the mixture at equilibrium and gave an appropriate explanation in terms of the number of moles of gaseous reactants and products in the equation. Some confusion was seen in answers relating the effect of increasing pressure on the rate of reaction.
- (ii) The idea that a higher temperature was required to increase the yield of this endothermic reaction was seen in many explanations. Inappropriate units, for example kJ/mol were seen and quite a few answers gave a value in degrees Celsius, even though the figure quoted in the question was in Kelvin. A small number of responses explained the use of an increase in temperature in terms of an increase in rate.

Question 2

- (a) The correct formula of aluminium oxide was often described; in some cases the formula of silicon(IV) oxide and/or phosphorus oxide was described incorrectly. The acid/base behaviour was less well known. Many answers described silicon(IV) oxide as amphoteric and responses that described sodium oxide as acidic and all the other oxides as basic were also seen.
- (b)(i) The majority of answers showed a good understanding of the term 'amphoteric'.
- (ii) Ionic equations representing the reaction between magnesium hydroxide and hydrochloric acid were rare. Many responses made no attempt to show the ionic equation but gave the full equation for the reaction. It was common to see the formula of magnesium chloride referred to as $MgCl$ rather than $MgCl_2$. Some answers attempted to show all the ions including the spectator ions.
- (iii) There were good answers, which gave detailed observed differences between the reactions of strontium and strontium hydroxide with water. Many answers did not include any observed difference or incorrectly stated that there would be effervescence when strontium hydroxide is added to water.
- (iv) The trend in solubility of Group 2 hydroxides was well known.

- (c) (i) Many responses used the ideal gas equation to find the amount of carbon dioxide. Of these, many converted the pressure, temperature and volume into the appropriate units and used the Data Booklet to find the gas constant.
- (ii) The majority of responses used the equation to appreciate the stoichiometry of the reaction between sodium peroxide and carbon dioxide. Correct calculations to find the mass of sodium peroxide using its formula mass and the answer produced in (c)(i) were common. Occasionally, the mass of carbon dioxide rather than sodium peroxide was calculated.
- (iii) Few answers showed correct 'dot-and cross' diagrams of the peroxide ion. Many responses showed the shared pair of electrons between the two oxygen species. Only a small number appreciated that there should be a total of 8 electrons on each oxygen ion to form the O_2^{2-} .

Question 3

- (a) (i) Relevant observations were described by many candidates. Some answers incorrectly described chlorine as a yellow gas rather than green or suggested that effervescence or a precipitate would be seen.
- (ii) Many correctly named the type of reaction of phosphorus pentachloride with water as hydrolysis. Hydration, neutralisation and redox were common incorrect answers.
- (iii) Good answers described the change in oxidation number of phosphorus and nitrogen and related these processes to oxidation and reduction. Many candidates appeared to have more difficulty deducing the oxidation numbers of nitrogen in the nitrogen containing species. The weakest responses described changes to the oxidation state of hydrogen and oxygen.
- (b) (i) The idea that a base is a proton donor was well known.
- (ii) Good three-dimensional representations of the ammonium ion and correct bond angle were seen. Weaker responses made no attempt to show the three-dimensional structure or produced confused diagrams. It was a relatively common mistake to see tetrahedral structures with two straight line bonds opposite each other, even though this suggests that the H–N–H is sitting in the same plane. Some answers suggested that the bond angle would be 107° rather than $109 - 109.5^\circ$.
- (iii) The majority appreciated that diammonium phosphate is used as a fertiliser.
- (c) (i) The reaction between phosphorus pentachloride and ethanol was not well known. The correct phosphorus containing product was rarely identified and it was common to see H_2O rather than HCl produced.
- (ii) Many candidates appreciated that a substitution reaction was involved when phosphorus pentachloride and ethanol react together to make ethanol.
- (iii) A small proportion of excellent descriptions explained why hydrogen iodide is not prepared using sulfuric acid. These answers identified sulfuric acid as a strong enough oxidising agent to oxidise hydrogen iodide to iodine. Some confused the iodine species involved during the reaction. The weakest responses discussed the thermal decomposition of hydrogen iodide.
- (iv) Many answers stated the correct trend in reactivity of the three halogenoalkanes. There were excellent responses, which explained this trend in terms of the increase in strength of the carbon–halogen bonds; there were a small number who quoted correct bond energies to support their answer. Weaker responses described 'decrease in bond strength down the group' but did not specify which bond they were referring to. Quite a few candidates stated that it was the hydrogen–halogen bond strength or difference in electronegativity of the halogens which was responsible for the difference in reactivity.

Question 4

- (a) There were some clear and accurate diagrams showing the mechanistic details for the reaction of **G** with hydroxide ions to make prenol. Many answers showed precise placing of the start and finish of a curly arrow to show the movement of an electron pair, either from a bond or a lone pair of electrons, to the new bond that is made. Some did not appreciate that the hydroxide ion is the nucleophile responsible for this reaction and attempted to show a mechanism involving Na–OH.
- (b) (i) In order to deduce the correct structure, candidates had to work out the three different isomers that could be made when prenol reacts with steam and then use the information that '**J** did not react with 2,4-DNPH' to deduce the structure of **J**. This was a demanding question, but correct structures of **J** were described by some. However, straight-chain molecules with two alcohol groups were common, even though the structure of prenol was given as a branched structure.
- (ii) Some candidates used all the information given to show a correct structure. Many answers showed a product with carbonyl groups or carboxylic acid groups, which suggested that some candidates were attempting to identify the compound made after oxidation with potassium dichromate(VI).
- (iii) In order to answer this question, details given in the stem of the question needed to be used; this included the idea that **K** and **L** are a pair of isomers formed when prenol reacts with steam. They both react with potassium dichromate to form the same compound, **M**. Although there were some answers that identified optical isomerism, many incorrect descriptions of geometric isomerism, chain isomerism and structural isomerism were seen.
- (iv) Writing balanced equations that represent the oxidising agent of the reaction as [O] proved difficult for many. Although some correct equations were seen, it was common for hydrogen gas rather than water to be described as a product and equations were rarely balanced.
- (c) (i) A description of the bromine water turning from brown to colourless to confirm the presence of the alkene group was common. A small number of answers described the addition of potassium manganate(VII), which would not be appropriate as it would also react with the primary alcohol group in a sample of prenol.
- (ii) Many answers described the correct repeat unit of poly(prenol). Where mistakes were seen, they often involved transcription errors or produced structures that showed a string of repeat units joined together with no identification of the repeat unit involved.
- (d) (i) Some candidates correctly named **N**; many others incorrectly identified the position of the methyl group and/or alcohol group and referred to it as 2-methylbutan-4-ol.
- (ii) Identification of nickel as a heterogenous catalyst was seen in many answers. There was confusion in some cases where words with 'hetero' were used but which had a totally different meaning, for example 'heterolytic' and 'heterozygous'.
- (iii) A significant number of answers showed correct skeletal structures of the ester made when isoprenol reacts with ethanol and sulfuric acid. Weaker responses had difficulty describing the ester link or showed an incorrect carbon backbone.
- The majority of answers identified a commercial use for **Q** as a perfume or solvent.
- (e) (i) Some candidates appreciated that the progress of the reaction could be followed by looking at the change in absorption within the range $1500\text{--}1680\text{ cm}^{-1}$, which corresponds to the disappearance of C=C. Weaker answers suggested that the absorbance which corresponded to the C–H bond could be monitored, even though C–H bonds are present in the reactant and the product.
- (ii) Identification of potassium cyanide or sodium cyanide to convert the chloroalkane into its corresponding nitrile was seen. Some responses incorrectly identified the reagents required to convert a carbonyl compound to a hydroxy-nitrile instead.
- (iii) Identification of the type of reaction involved in the conversion of a nitrile to its corresponding carboxylic acid was well known. The most detailed answers described it as acid hydrolysis but the majority referred to the reaction as hydrolysis.

- (iv) This was a demanding question. A small number of detailed explanations related the low yield to the unstable primary carbocation made during this reaction. Many answers were seen that discussed rate of reaction, activation energy and bond strength to the low yield but did not attempt to explain that another product could be formed from an intermediate with a greater positive inductive effect.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key messages

- The importance of basic mathematical skills to successfully study chemistry cannot be over emphasised. There were many instances when the lack of simple mathematical techniques led to errors and consequently the loss of valuable marks.
- When questions require a single answer, there appears to be a trend for candidates to offer more than one response. This can lead to a contradiction or errors resulting in the loss of credit.
- Observations should include something that is seen, heard or noticed.
- Candidates should avoid vague references to 'it' in their responses, as it is not always clear what the 'it' refers to.

General comments

Practical related topics requiring answers to include observations appeared to present problems for many candidates.

The concept of the boiling of giant covalent or simple molecular compounds was challenging for many candidates.

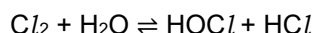
Mechanisms caused many candidates problems; a curly arrow represents the movement of two electrons, either from the middle of a covalent bond or from a lone pair of electrons, to the recipient atom. Many mechanisms showed curly arrows either coming from an atom or from a point well away from the lone pair of electrons.

Comments on specific questions

Question 1

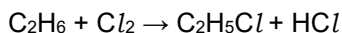
- (a) (i) The oxidising action of MnO_2 was often correctly answered by referring to the change in oxidation number of Mn (in MnO_2) from +4 to +2 (in MnCl_2). In a few instances, the change in oxidation number of Cl (in HCl) from -1 to 0 (in Cl_2) was also correctly given. A few answers non-specifically referred to the change in oxidation number of MnO_2 or just 'it' and were not creditworthy.
- (ii) The correct observations for the reaction between MnO_2 and HCl include 'effervescence', a 'green/yellow-green gas' and the 'solid dissolves'. Many answers referred to 'it' dissolves or ' MnO_2 ' dissolves, neither of which is an actual observation.
- (b) The trend in volatility of the Group 17 elements, $\text{Cl}_2(\text{g})$, $\text{Br}_2(\text{l})$ and $\text{I}_2(\text{s})$, was well answered. On a number of occasions 'volatility' was confused with 'boiling point'. Explanation of the decrease in volatility down the Group required mention of the increase in the strength of a specific intermolecular force, *induced dipoles*, as a result of an increase in the number of electrons.
- (c) (i) Answers explaining that chlorine undergoes disproportionation by being both oxidised and reduced in the same reaction were generally good. Equations to support the explanations were confused on occasions, with both HCl and HClO appearing as products for a reaction between NaOH and Cl_2 .
- (ii) Hot aqueous NaOH reacts with chlorine to form NaClO_3 , sodium chlorate(V); this question was generally well answered.

- (d) Chlorine is used as a disinfectant and added to water supplies to 'kill' pathogens, which is attributed to the action of HOCl , in acid solution:



Many answers correctly identified that the chlorine is added to water supplies, to 'kill' the pathogens; fewer correctly identified that the HOCl was the species responsible for this activity.

- (e) (i) The use of UV light to initiate the free-radical substitution reaction was widely known.
(ii) The **overall** equation for the reaction of chlorine with ethane was poorly answered.



Several answers started with CH_4 and contained a free radical in the equation or omitted HCl as a product.

Question 2

- (a) The bonding in some of the oxides of Period 3 elements was generally correct but the structure of each of the oxides was less well answered. Each of the ionic lattices Na_2O , MgO and Al_2O_3 , together with SiO_2 are described as giant structures, whereas SO_2 is molecular.
- (b) (i) The different boiling points of SiO_2 and SO_3 are associated with the difference in energy required to break the many actual covalent bonds, in SiO_2 , compared to the much weaker intermolecular forces of attraction, (IMFs), between the SO_3 molecules. Many candidates struggled with the concept of boiling and referred to weaker bonds in SO_3 compared to SiO_2 , whereas a quick check of bond energies in the *Data Booklet*, would have revealed that the difference between the bond energies for Si-O and S-O, is a mere 100 kJ mol^{-1} . SiO_2 has a large number of covalent bonds which are broken when it boils, but SO_3 has only comparatively very weak IMFs and thus the large difference in energy required to break many covalent bonds compared to weak intermolecular was lacking in many answers.
- (ii) The amphoteric nature of Al_2O_3 was well understood and the balanced equation for its reaction with an acid was well answered. However, the reaction of Al_2O_3 with an alkali was less well known, with many unbalanced equations because of the omission of H_2O from the reactant side of the equation.
- (iii) Observations when chemicals are mixed often proves challenging; in this instance many candidates gave answers consistent with adding sodium to water and not the oxide of sodium and water. When the solid, (Na_2O), is added to water, the solid dissolves to form a colourless solution.
- (c) (i) The octahedral shape of SeF_6 was well known.
- (ii) Candidates who appreciated that this enthalpy calculation involved the breaking of one $\text{Se}=\text{O}$ bond and the forming of two $\text{Se}-\text{O}$ bonds, in the polymeric reaction, tended to be awarded both marks.
- (iii) Several candidates misread the question and used SO_2 , instead of SeO_2 and many more candidates incorrectly gave H_2 and Na_2SeO_4 as products.

Question 3

- (a) (i) The process of breaking down long-chain hydrocarbons into shorter-chain hydrocarbons is called cracking. Many correct answers were seen.
- (ii) Low molecular mass hydrocarbons are used as fuels because they release a large amount of energy, burn cleanly and combust easily. Many responses focused on the 'volatility', low activation energy and aspects of pollution of the fuels, rather than appreciating that fuels are substances that are used to provide heat or power.

- (iii) Many candidates were awarded credit for correctly giving balanced equations showing the incomplete combustion of butane to form carbon monoxide as one of the products.
- (iv) The majority of responses were not creditworthy. Many described the use of either a 'catalytic converter', to calculate the amount of CO in the atmosphere, or fractional distillation of air to separate the CO. Infrared spectroscopy is frequently used to detect and monitor the levels of CO in the atmosphere by observing the level of the characteristic peak for the CO absorption.
- (b) (i) During reactions involving complete combustion the elements in a compound are burned and the products are primarily the most common oxides. The products from the complete combustion of thiophene, $C_4H_4S(l)$, are carbon dioxide, water and sulfur dioxide. Many answers gave the correct products and state symbols; the most common errors included stating sulfur, S, as a product and gas, (g), as a state symbol for water.
- (ii) Several definitions of the *enthalpy change of combustion* incorrectly stated that it was the 'energy/enthalpy required' for the combustion reaction. The key points of 'one mole of substance' and 'excess oxygen' were frequently missing.
- (iii) The majority of answers for the heat energy released when a certain mass of thiophene is combusted were correct. The most common errors included using 0.2 g, instead of 200 g, for the mass of water and adding 273 to the temperature change.
- (iv) The majority of answers correctly calculated the enthalpy change of combustion by dividing the heat energy released by the moles of thiophene. However, many candidates did not appreciate that if the temperature increased during the combustion, then the enthalpy change must be accompanied by a negative sign (-).

Question 4

- (a) (i) The naming of $(CH_3)_3CCHO$, was challenging for the majority of candidates. The longest chain contains three carbon atoms, one of which is contained within an aldehyde group, and two methyl groups are attached to the number 2 carbon atom. The name is thus 2,2-dimethylpropanal. The common errors were to omit the second 2, in 2,2- and the prefix 'di' when referring to the two methyl groups, on the second C atom.
- (ii) When candidates understood what is meant by the term *hybridisation*, this question was well answered. The most common error was mention of sp^3 , instead of the correct answer of sp^2 .
- (b) (i) The common reagent and conditions for an oxidation reaction involving an aldehyde group, is acidified potassium dichromate(VI) and heating under reflux. This question was well answered but some responses omitted 'acidified' or 'heat'.
- (ii) This question directed the candidates towards the use of intermolecular forces, (IMFs), in their answers. It required them to identify hydrogen bonds as the principal IMF in the solid carboxylic acid, **A**, $(CH_3)_3CCO_2H$ and dipole-dipole forces, in the liquid ester, **B**, $CH_3CO_2(CH_2)_2CH_3$. They needed to appreciate that H-bonding is the stronger IMF and will contribute to a compound being solid rather than a liquid. Several responses focused on the effect of branching, whilst others concentrated on chain length and surface contact, instead of identifying the different type of IMF in each compound.
- (iii) The equation for the reduction of $(CH_3)_3CCHO$ using $NaBH_4$ as the reducing agent, proved challenging for many candidates. Some answers contained $NaBH_4$ as a reactant, whereas the question directed the use of $[H]$ to represent the reducing agent. Other answers did not use $2[H]$, as a reactant and/or missed a C atom in the product.
- (iv) Many candidates recognised that the reaction of **A**, $(CH_3)_3CCO_2H$, with **T** involved an esterification reaction and correctly identified **T** as propan-2-ol, $(CH_3)_2CHOH$, using a catalyst, conc. H_2SO_4 or conc. H_3PO_4 .
- (c) (i) The majority of answers correctly stated that orange/red/yellow precipitates are observed when 2,4-DNPH is reacted separately with **X** and **Y**.

- (ii) The assigning of an aldehyde functional to the positive test with Fehling's solution was well answered. The most common incorrect answer was carbonyl or C=O.
- (iii) The definition of the term *chiral centre* was quite well answered. The most common errors were omitting that the four different groups/atoms are bonded/attached to a carbon atom and also referring to four different groups as 'molecules/compounds or ions'.
- (iv) Incorrect 3-D diagrams for the optical isomers of **Y** were quite common. Some structures contained three CH₃ groups, two linear solid bonds at 180° to each other or four different representations of covalent bonds.
- (v) This was a well answered question, with the majority of candidates stating the correct bonds for all three absorptions.
- (vi) Many answers gained credit for correctly drawing a skeletal representation of an alkene, **Z**, containing a C5 structure and an alcohol group. The question stated that **Z** was branched and showed *geometrical isomerism*; many candidates either did not note these requirements or were not aware of the criteria for a compound to exhibit geometric isomers. Many structures were either straight chain or contained two terminal methyl groups.
- (vii) This mechanism was generally poorly answered. The structure of **X**, (C₂H₅)₂C=O, with the correct polarity on the C=O group was the most common mark credited. Many candidates incorrectly showed arrows originating from the C atom, of the C=O group, rather than the middle of the π bond, or arrows not specifically from a lone pair of electrons. Many intermediate structures correctly showed a negative charge on the O atom, but there was no CN group bonded to the C, of the original C=O group.
- (viii) The catalytic role of the presence of a small amount of NaCN in this reaction was generally well recognised.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the Supervisor's experimental results.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

The standard of experimental skills varied considerably and was generally centre dependent. Most candidates were able to gain credit in **(a)** and **(b)**. Credit for the rest of the analysis and conclusion sections were gained by those showing understanding of the effects of altering quantities of reagents on the rate of a reaction.

- (a)** Most candidates gained credit for recording results. The errors seen included 'weight' instead of 'mass', omission of units or incorrect units. The unit of volume used in 9701 is always based on the SI unit of m^3 , i.e. cm^3 or dm^3 . Hence, ml is not appropriate even though some manufacturers use this. The accuracy marks tended to be centre-dependent and indicated that some candidates were much more familiar with this type of experiment than others. In a few centres, the candidates' volumes of gas collected varied by over 100 cm^3 ; others reported volumes all within a realistic range of each other and of the Supervisor.

- (b) Most candidates knew how to calculate the number of moles of gas from its volume in (i). A few candidates omitted the division by 1000 to convert their answer from cm^3 to dm^3 . The stoichiometry of the equation was recognised by the majority of candidates and many were able to calculate the concentration of hydrochloric acid and the mass of magnesium. Some candidates inappropriately gave their answer to one, five or five or more significant figures in any of (i) to (iii).
- (c) For suggestion 1, many candidates correctly recognised that the reaction would be slower; far fewer went on to state this meant that the experiment was more accurate because less gas would escape before the bung was fitted.
- For suggestion 2, more candidates realised that, since the magnesium was already in excess, the use of twice as much would not affect the volume of gas and hence the determination of the concentration of hydrochloric acid.
- (d) A satisfactory explanation was only given by better performing candidates. A significant number of candidates stated that less hydrochloric acid would react; fewer related this to the experimentally measured volume of hydrogen produced and hence the reduced concentration of the acid.

Question 2

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method, the presentation of results and the calculation using the titration data. However, many candidates had difficulties with the sections dealing with errors.

- (a) The results in this part tended to be centre-dependent. The common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place, and not providing a concordant last titre. In some centres, there was little agreement amongst a candidate's titres, amongst the candidates or between the candidates and supervisor.
- (b) The majority of candidates gained credit for the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3 .
- (c) (i) Answers to (ii) to (iv) were expected to be given to three or four significant figures. A number of candidates recognised this fact and therefore wrote three or four significant figures in (i) but then did not actually give answer to this correct degree of accuracy.
- (ii)(iii) Most candidates calculated the moles of HCl and its concentration in **FA 4** correctly. A common error was dropping a trailing zero in (ii). An answer to two significant figures does not reflect the precision given for the concentrations nor that of the apparatus used.
- (iv) Few candidates calculated this concentration correctly. It was necessary to use the original volume of **FA 2** as well as the 250 cm^3 to which this was diluted.
- (d) A significant number of correct answers were seen. Many other candidates did not realise that although the error in a burette reading is 0.05 cm^3 , the addition of a volume of **FA 2** involved two burette readings so that the overall error was 0.1 cm^3 . Others found the percentage based on volumes other than that of the original **FA 2**.
- (e) Candidates performed poorly on this part. Candidates should be given the opportunity to discuss errors and improvements when carrying out practical exercises in class. In both **Question 1** and **Question 2**, better performing candidates gave precise explanations. In **Question 1**, some candidates suggested using a burette or pipette instead of a measuring cylinder without commenting on the increased accuracy and so could not be credited. In **Question 2**, few acceptable answers were seen. Answers based on human error, use of an assistant or camera are never credited.

Question 3

This proved to be difficult for many, although some good responses were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It is useful if supervisor results are included since, if unexpected observations are made, it is possible to see whether these were due to poor technique or to contamination of the chemical supplied.

- (a) (i) Where the instructions specify 'all your observations', this implies that several changes will occur. In this case, three or more observations were expected.
- (ii) Where aqueous sodium hydroxide or aqueous ammonia are specified in tests, it is essential that they are added to excess and that the observations includes the phrase 'soluble in **excess**' or 'not soluble in **excess**'. By definition a precipitate cannot be soluble. When a reagent is warmed with sodium hydroxide, it must be specified that it is the gas or ammonia that is changing the litmus to blue since, without this, it could be the aqueous sodium hydroxide.
- (iii) Many candidates suggested two correct ions; fewer gave all three.
- (b) Several approaches could be used to determine this formula. Candidates were able to suggest a formula in which the positive charges on their number of potassium and chromium ions were the same as the number of negative charges on their sulfate ions. Better performing candidates went on to use the relative formula mass to calculate the number of moles of water.
- (c) (i) A significant number of correct observations were seen. Candidates who followed the instruction only to add a few drops of potassium manganate(VII) should not have produced enough iodine to form a precipitate.
- (ii) A number of correct answers were seen. Few recognised the significance of the test with starch and a number followed their incorrect observation of a grey-green precipitate by identifying the ion present as Cr^{3+} . Many candidates correctly identified Fe^{2+} .
- (iii) Candidates found writing ionic equations challenging. Many did not balance the number of OH^- ions needed and many omitted or gave incorrect state symbols. This is an area of the syllabus which candidates would benefit from further practice.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the Supervisor's experimental results.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method and the presentation of results. The calculation caused problems for some, as parts of the information given in the question were disregarded by candidates.

- (a) The results in this part tended to be centre-dependent. The common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place and not providing a concordant last titre.
- (b) The majority of candidates determined the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm³.
- (c) (i) Candidates are instructed to show appropriate significant figures in final answers to all parts and they were reminded of this in (i); any answer that was not to three or four significant figures was not credited.

- (ii) Many candidates calculated the moles of NaOH correctly. Some candidates omitted dividing by the relative formula mass or dividing by 1000.
- (iii) Nearly all candidates gave the correct equation; many gave incorrect state symbols. The common errors were NaCl(s), contrary to what they would have observed in the titration, and H₂O(aq). Almost all candidates realised that the number of moles of HCl would be the same as the moles of NaOH.
- (iv) The calculation of the concentration of HCl in **FA 2** proved to be the most challenging part of the question for many. Several approaches were seen; it was important that the steps employed to calculate this concentration are logical and clearly displayed on the candidate's script. Many candidates only multiplied their answer in (iii) by 100, which was incorrect.

Question 2

Many candidates gained good results in both of their experiments. The responses in the rest of the question varied considerably. A wide spread of marks was seen in the analysis, conclusions and improvements sections.

- (a) The majority of candidates recorded their results in a clear, logical manner. The most common error was to record thermometer readings either to an integer value or to .00 °C. A large majority of candidates reported an increase in temperature. The ΔT values varied considerably from centre to centre with some being as low as 5.0 °C and others as high as 45.0 °C. This highlights the importance of including supervisor with the return of candidate scripts.
- (b) The responses to this section appeared to be largely centre-dependent, with many obtaining full marks but others gaining none or one.
 - (i) This part was answered correctly by most candidates with almost all knowing the equation to find the heat energy produced. The most common error was to use the mass of MgO instead of the volume of solution, thus ignoring the information given regarding 4.2 J being required to change the temperature of 1.0 cm³ by 1.0 °C.
 - (ii) This was also answered correctly by a large majority of candidates. Some candidates, incorrectly, used 24 as the relative atomic mass, A_r , of Mg instead of 24.3, as given in the Periodic Table on the question paper.
 - (iii) Most candidates used their answers to (i) and (ii) correctly. Some incorrectly gave a positive sign for an exothermic reaction, gave an answer to five or more significant figures, or did not divide by 1000 to convert J into kJ.
- (c) Better performing candidates answered this section successfully; many others did not attempt it. Of those who did, most were able to calculate the moles of HCl used in (a) but did not apply the stoichiometry of the equation so could not access the mark.
- (d)
 - (i) Most candidates performed well with very few using a mass of MgCO₃ outside the range specified. There was greater agreement between centres for the value of ΔT in this part than in (a).
 - (ii) Most candidates reported fizzing or effervescence; far fewer commented on the vigour of the reaction and even fewer the colour of the solution formed. The question asked for observations so more than one observation was expected.
 - (iii) There were many correct answers here. Those using the mass of MgO in (b)(i) tended to use the mass of MgCO₃ in the heat energy change. A few used the number of moles of MgO from (b)(ii) instead of calculating and using the moles of MgCO₃.
- (e) Many candidates sketched a Hess' diagram to help them with the calculation. Some were less successful as they had arrows going the wrong way; a common error was to subtract (b)(iii) from (d)(iii). Some candidates ignored their own results and used the default values; this was allowed in all cases. As reversing the equation would show a thermal decomposition reaction it was expected that candidates would recognise that MgO(s) + CO₂(g) → MgCO₃(s) would be exothermic.

- (f) Credit was rarely awarded as most answers involved changes to the apparatus, despite the wording of the question. Of those gaining credit, the majority suggested increasing the mass of **FA 4** and/or **FA 5**; only a small minority suggested collecting results for plotting a cooling curve.
- (g) It was rare to award both marks and some candidates scored zero. Many candidates correctly identified a single reading error for the balance; far fewer doubled this for calculating the maximum percentage error in the mass of MgO calculated in (a).

Question 3

This proved to be difficult for many though some high marks were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It was noticeable that few supervisors provided observations in (a), (b)(i) and (b)(ii), which made it difficult to ascertain whether unexpected observations were due to poor technique or to contamination of the chemical supplied.

- (a) Most candidates recorded effervescence; far fewer went on to test the gas. Many assumed the gas was CO_2 from a carbonate and claimed it formed a white precipitate with limewater. Of those correctly identifying H_2 as popping with a lighted splint, only a small number went on to suggest that **FA 6** was a metal.
- (b)(i) Few candidates supplied enough correct observations to gain more than one mark. Most candidates noted the melting of **FA 7** but rarely reported that the liquid turned yellow. Some candidates noted effervescence on further heating; far fewer tested the gas with a glowing splint. Many used incorrect terminology for the change observed on cooling; the use of the term 'precipitate' was inappropriate. Only a few candidates included the colour of the solid formed.
- (ii) Responses to this part varied considerably and it was rare to award full credit. It was insufficient in test 1 to write 'colourless solution' when adding acidified aqueous potassium manganate(VII) to **FA 9** as this did not indicate the change in colour of the reagent. Some candidates lost credit in test 2 by adding an acid to the precipitate formed with **FA 9**, even though the initial instructions stated that no additional tests should be carried out. Many candidates reported effervescence on adding aluminium foil in test 3 and correctly identified NH_3 produced with **FA 8**. However, red litmus paper was also reported as turning blue with **FA 9**, which suggested poor technique. Very few candidates tested for H_2 .
- (iii) Correct names or formulae were often given. Some candidates did not attempt this part or suggestion ions such as Cl^- even though no test for halides had been carried out.
- (iv) There were few correct answers given, with many candidates appearing to have a poor understanding of ionic equations. Of those giving a correct equation, many omitted state symbols or gave incorrect ones; $\text{BaSO}_4(\text{aq})/\text{BaSO}_3(\text{aq})$ was a common error. A number of 'insoluble' compounds of sodium were suggested.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

The standard of experimental skills varied considerably and was generally centre-dependent. Most candidates were able to gain credit in **(a)** and **(b)**. Credit for the rest of the analysis and conclusion sections was only awarded by those able to explain how their knowledge of rates of reaction applies to the questions set.

- (a)** Most candidates gained credit for presentation of results. The errors seen included use of the word 'weight' instead of 'mass' and omission of units or quoting incorrect units. The unit of volume used in 9701 chemistry is always based on the SI unit of m^3 , i.e. cm^3 or dm^3 . Hence, m^3 is not appropriate even though some manufacturers use this. The accuracy marks tended to be centre-dependent and indicated that some candidates were much more familiar with this type of experiment than others. In a few centres, the candidates' volumes of gas collected varied by over 100 cm^3 , while others reported volumes all within a realistic range of each other and of the supervisor.

- (b)(i)(ii)** Most candidates calculated the number of moles of oxygen collected in 4 minutes. Some candidates omitted the division by 1000 to convert their answer from cm^3 to dm^3 . The stoichiometry of the equation was ignored by the majority of candidates. However, many gained credit by dividing their number of moles by 0.03 dm^3 , the volume of **FB 1** used. Some candidates inappropriately gave their answer to one, five or five or more significant figures in either **(i)** or **(ii)**.
- (c)** A number of candidates incorrectly agreed with the 'candidate' even though their experimental results contradicted the statement. Many candidates failed to explain that the decrease in rate was caused by a decrease in frequency of collision owing to decreased concentration.
- (d)** The most common correct response was that there would be no change in the final volume of gas collected as MnO_2 was a catalyst. However, many responses were vague; for example, 'faster reaction' needed clarification. The response of 'no effect' needed clarifying with 'on final volume' as the question asked about results obtained.

Question 2

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method, the presentation of results and the calculation using the titration data. However, many candidates had difficulties with the sections dealing with errors.

- (a)** The results in this part tended to be centre-dependent. Common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place and not providing a concordant last titre.
- (b)** The majority of candidates determined the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3 .
- (c) (i)** Most candidates calculated the moles of potassium manganate(VII) correctly.
- (ii)** Most candidates calculated the moles of hydrogen peroxide correctly.
- (iii)** Most candidates calculated the concentration of hydrogen peroxide correctly; others dropped a trailing zero. An answer to two significant figures did not reflect the precision given for the concentration of the oxidising agent nor that of the apparatus used; three or four significant figures should have been shown.
- (d)** Candidates struggled to adequately answer this question. Candidates should be given the opportunity to discuss errors and improvements when carrying out practical exercises in class. The most frequently seen credit-worthy error and improvement involved the loss of gas and the use of a divided flask or similar. (An example of a discussion point for teachers and learners could be the reason that using a thistle funnel to add the hydrogen peroxide is unsuitable.) Some candidates suggested using a burette instead of a measuring cylinder without specifying which one it was replacing. Answers based on human error, use of an assistant or camera are never credited.
- (e)** A minority of candidates correctly stated the acid was in excess, so the volume added need not be accurate. Many candidates agreed with the 'student' and gave examples of error for each of a pipette and a measuring cylinder. Others, incorrectly, stated that a pipette could not measure 20 cm^3 , these candidates were not aware of the range of pipette volumes available or graduated pipettes. A minority of candidates suggested that it would be dangerous to pipette the acid by mouth, these candidates did not appear to be aware of pipette fillers. These are examples of where class discussion would be beneficial.

- (f) (i) The calculation was carried out correctly by a small majority of candidates. Every combination of the figures was seen; the most common errors were to divide by the actual rather than the theoretical concentration or to divide by the mean of the two values.
- (ii) Only a minority of candidates were aware of the slow decomposition of hydrogen peroxide at room temperature.

Question 3

This proved to be difficult for many candidates, although some good responses were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It was noticeable that few Supervisors provided observations in (a)(i), which made it difficult to ascertain whether unexpected observations were due to poor technique or to contamination of the chemical supplied.

- (a) (i) It was insufficient in test 1 to write 'colourless solution' when adding acidified aqueous potassium manganate(VII) to **FB 7**, as this did not indicate the change in colour of the reagent. Use of the Qualitative Analysis Notes would have been of assistance to some in test 2, as the effect of adding excess NaOH(aq) to the precipitate with **FB 6** was often omitted. It was apparent from the bubbling reported that many candidates boiled the alkaline mixtures rather than just warming sufficiently for any ammonium ion present to react. Many candidates gave false positives for ammonia gas in this test. Many candidates noted the red-brown precipitate in the final part of test 3 with **FB 7**; fewer noted effervescence with H₂O₂(aq) or that the precipitate was insoluble in excess NaOH(aq). The words 'in excess' were essential as, by definition, precipitates are insoluble so 'red-brown precipitate insoluble' is insufficient. Test 4 produced many correct observations but some candidates added an acid to the precipitates formed with Ba²⁺(aq), thus disregarding the initial instruction that 'no additional tests should be attempted'. There was a mixed response to test 5. 'Ammonia produced', is a conclusion and not an observation so could not be credited. While some candidates noted effervescence in both the tests using NaOH(aq) and Al foil, others only commented on the change of colour of red litmus paper. Candidates should be aware that hydrogen gas is formed in this test and so be prepared to prove its presence. Few candidates reported a pop with a lighted splint with **FB 7** and many incorrectly reported the red litmus turning blue. Unless there was some indication that a gas was being tested, then the red to blue with **FB 8** could not be credited.

(ii)-(v)

The most common error in this section was to omit a reason for the choice of ion. The relevant reagents should also have been mentioned. Some candidates confused cations and anions.

Most candidates recognised the cation Fe²⁺ in (ii) and knew the two possible anions, SO₃²⁻ and SO₄²⁻, in (iii). Most were able to name a cation in (iv) that could not be present, but many did not specify that this was shown by the negative result when tested with NaOH(aq). It was essential for candidates to indicate that the ammonia was formed on adding Al foil as well as NaOH(aq) to the NO₃⁻ in (v).

- (b) This part was poorly answered by many; nevertheless, some candidates gained full credit. Some candidates were able to draw an appropriate table and include at least one test. Few candidates suggested suitable named reagents and the conditions needed for an esterification test. Most of those who stated propan-1-ol suggested using acidified potassium manganate(VII) or acidified potassium dichromate(VI), although the colour changes for the latter were not always correct. The most popular test for gaining a positive result with ethanoic acid was the addition of a named carbonate and noting effervescence or testing the gas with limewater. There were many incorrect reagents suggested such as Na, PCl₅ and SOCl₂; these would have reacted with both organic compounds. Other reagents suggested were only suitable for identifying the presence of an aldehyde or a CH₃CH(OH)-/CH₃CO- group.

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Paper 9701/35
Advanced Practical Skills 1

Key messages

- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.
- Candidates are encouraged to practise writing ionic equations including state symbols.

General comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the Supervisor's experimental results.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

The standard of experimental skills varied considerably and was generally centre dependent. Most candidates were able to gain credit in **(a)** and **(b)**. Credit for the rest of the analysis and conclusion sections were gained by those showing understanding of the effects of altering quantities of reagents on the rate of a reaction.

- (a)** Most candidates gained credit for recording results. The errors seen included 'weight' instead of 'mass', omission of units or incorrect units. The unit of volume used in 9701 is always based on the SI unit of m^3 , i.e. cm^3 or dm^3 . Hence, ml is not appropriate even though some manufacturers use this. The accuracy marks tended to be centre-dependent and indicated that some candidates were much more familiar with this type of experiment than others. In a few centres, the candidates' volumes of gas collected varied by over 100 cm^3 ; others reported volumes all within a realistic range of each other and of the Supervisor.

- (b) Most candidates knew how to calculate the number of moles of gas from its volume in (i). A few candidates omitted the division by 1000 to convert their answer from cm^3 to dm^3 . The stoichiometry of the equation was recognised by the majority of candidates and many were able to calculate the concentration of hydrochloric acid and the mass of magnesium. Some candidates inappropriately gave their answer to one, five or five or more significant figures in any of (i) to (iii).
- (c) For suggestion 1, many candidates correctly recognised that the reaction would be slower; far fewer went on to state this meant that the experiment was more accurate because less gas would escape before the bung was fitted.
- For suggestion 2, more candidates realised that, since the magnesium was already in excess, the use of twice as much would not affect the volume of gas and hence the determination of the concentration of hydrochloric acid.
- (d) A satisfactory explanation was only given by better performing candidates. A significant number of candidates stated that less hydrochloric acid would react; fewer related this to the experimentally measured volume of hydrogen produced and hence the reduced concentration of the acid.

Question 2

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method, the presentation of results and the calculation using the titration data. However, many candidates had difficulties with the sections dealing with errors.

- (a) The results in this part tended to be centre-dependent. The common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place, and not providing a concordant last titre. In some centres, there was little agreement amongst a candidate's titres, amongst the candidates or between the candidates and supervisor.
- (b) The majority of candidates gained credit for the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3 .
- (c) (i) Answers to (ii) to (iv) were expected to be given to three or four significant figures. A number of candidates recognised this fact and therefore wrote three or four significant figures in (i) but then did not actually give answer to this correct degree of accuracy.
- (ii)(iii) Most candidates calculated the moles of HCl and its concentration in **FA 4** correctly. A common error was dropping a trailing zero in (ii). An answer to two significant figures does not reflect the precision given for the concentrations nor that of the apparatus used.
- (iv) Few candidates calculated this concentration correctly. It was necessary to use the original volume of **FA 2** as well as the 250 cm^3 to which this was diluted.
- (d) A significant number of correct answers were seen. Many other candidates did not realise that although the error in a burette reading is 0.05 cm^3 , the addition of a volume of **FA 2** involved two burette readings so that the overall error was 0.1 cm^3 . Others found the percentage based on volumes other than that of the original **FA 2**.
- (e) Candidates performed poorly on this part. Candidates should be given the opportunity to discuss errors and improvements when carrying out practical exercises in class. In both **Question 1** and **Question 2**, better performing candidates gave precise explanations. In **Question 1**, some candidates suggested using a burette or pipette instead of a measuring cylinder without commenting on the increased accuracy and so could not be credited. In **Question 2**, few acceptable answers were seen. Answers based on human error, use of an assistant or camera are never credited.

Question 3

This proved to be difficult for many, although some good responses were seen. A common error was to ignore the initial Qualitative Analysis instructions regarding testing of any gases seen and the changing of colours. It is useful if supervisor results are included since, if unexpected observations are made, it is possible to see whether these were due to poor technique or to contamination of the chemical supplied.

- (a) (i) Where the instructions specify ‘**all** your observations’, this implies that several changes will occur. In this case, three or more observations were expected.
- (ii) Where aqueous sodium hydroxide or aqueous ammonia are specified in tests, it is essential that they are added to excess and that the observations includes the phrase ‘soluble in **excess**’ or ‘not soluble in **excess**’. By definition a precipitate cannot be soluble. When a reagent is warmed with sodium hydroxide, it must be specified that it is the gas or ammonia that is changing the litmus to blue since, without this, it could be the aqueous sodium hydroxide.
- (iii) Many candidates suggested two correct ions; fewer gave all three.
- (b) Several approaches could be used to determine this formula. Candidates were able to suggest a formula in which the positive charges on their number of potassium and chromium ions were the same as the number of negative charges on their sulfate ions. Better performing candidates went on to use the relative formula mass to calculate the number of moles of water.
- (c) (i) A significant number of correct observations were seen. Candidates who followed the instruction only to add a few drops of potassium manganate(VII) should not have produced enough iodine to form a precipitate.
- (ii) A number of correct answers were seen. Few recognised the significance of the test with starch and a number followed their incorrect observation of a grey-green precipitate by identifying the ion present as Cr^{3+} . Many candidates correctly identified Fe^{2+} .
- (iii) Candidates found writing ionic equations challenging. Many did not balance the number of OH^- ions needed and many omitted or gave incorrect state symbols. This is an area of the syllabus which candidates would benefit from further practice.

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Paper 9701/36
Advanced Practical Skills 2

Key messages

- Candidates should record readings to the precision of the apparatus used. This is normally to half a division of the calibrated scale.
- Candidates should quote numerical answers to the number of significant figures that reflects the data provided regarding the reactants and the errors inherent in the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Candidates should be given the opportunity to discuss errors arising in the practical methods during their studies and identify possible improvements to ameliorate these.

General comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the supervisor's experimental results.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of supervisor's results. It was noticeable that far fewer supervisors provided observations for tests in **Question 3** than for the other two questions. Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

Many candidates were able to complete the practical work to a high standard. This was a straightforward titration exercise and it was apparent that most candidates were well acquainted with the method, the presentation of results and the calculations using the titration data.

- (a) The results tended to be centre-dependent. The common errors were omitting the burette readings for the rough titration, recording the accurate burette readings to an integer or only one decimal place and not providing a concordant last titre. In some centres, there was little agreement between a candidate's titres, amongst the candidates or between the candidates and Supervisor.

- (b) The majority of candidates gained credit for the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3 .
- (c) (i) Answers to (ii) to (v) were expected to be given to three or four significant figures, since this was the accuracy of the measuring apparatus used and of the other data.
- (ii) Most candidates used the volume of solution in (b) and the concentration of hydrochloric acid; few realised that **FB 3** had been prepared by diluting **FB 2** so that the number of moles of HCl was actually this value divided by 10.
- (iii) The stoichiometry of the equation was used by most to correctly calculate the number of moles of Ca(OH)_2 .
- (iv) The required multiplication by 40 was generally correct.
- (v) The most common error was using the A_r of calcium as 40, rather than 40.1 given in the Periodic Table supplied.

Question 2

Most candidates were familiar with exercises designed to determine enthalpies of reaction and produced temperature changes that were reasonable for the chemicals used. The supervisor's and candidates' temperature changes in a few centres suggested that the chemicals were incorrect or contaminated in some way. The reactions in both (a) and (b) are considerably exothermic so temperature falls or very small rises indicates a problem.

- (a) (i) Most data was correctly recorded, with very few candidates including 'weight' rather than 'mass'. Temperature readings throughout the experiment had to be quoted to half a degree i.e. end in .0 or .5.
- (ii) Nearly all candidates used $\text{energy} = mc\Delta T$, with the most common error being quoting the mass of the solid added rather than that of the solution.
- (iii)(iv) Most candidates attempted a correct method in each part, with only a minority quoting answers to an incorrect number of significant figures, forgetting to divide by 1000 or giving the sign of the final enthalpy change as +.
- (b) (i) Most data was correctly recorded, with very few candidates including 'weight' rather than 'mass'. Temperature readings throughout the experiment had to be quoted to half a degree i.e. end in .0 or .5.
- (ii) The most common error was quoting the mass as that of the solid added rather than that of the solution.
- (c) Better performing candidates tended to show some working and hence reach a correct conclusion.
- (d)(i)(ii) Candidates found these parts challenging. Teachers are advised that when candidates have carried out a practical exercise in class, they should discuss the effects of altering reagents/condition, possible sources of error and methods of minimising the effects of the errors.

In (i), many candidates said that the temperature would rise because there was more acid present. This was in spite of the information, at the start of the question, that the acid was already in excess.

In (ii), many said that there would be no effect without explaining why.

Question 3

Parts of this question proved to be difficult, although some good responses were seen. Candidates should be advised to consider, before they carry out a test, what observations are likely to occur so that they can be prepared.

(a) Where the instructions specify 'all your observations', this implies that several changes will occur. In this case, three or more observations were expected. Few candidates gave as many as this and a significant number did not identify the gas produced, despite specific instructions in the question to do so. Better performing candidates had thought through which gases were likely to be given off when the solid was heated and were prepared with appropriate apparatus ready to test for these gases.

(b)(i) Precise descriptions of colour changes are needed so that, for example with **FB 9** and manganate(VII), it was necessary to include the starting colour of the manganate(VII) or state that it was manganate(VII) that was being decolourised. It was insufficient to say 'colourless', as **FB 9** is already colourless.

In the test with silver nitrate, it is essential that the description of the colour of the precipitate formed matches that given in the Qualitative Analysis Notes. In this case the precipitate given with **FB 8** should be described as yellow.

FB 9 did react with warmed sodium hydroxide and aluminium to produce ammonia, but **FB 8** did not; the gas produced in this case was hydrogen, formed by the reaction of the aluminium with warmed aqueous sodium hydroxide. A number of candidates claimed to produce ammonia in this test.

(ii) A significant number of correct ionic equations were seen.

(iii) This part was poorly answered by many, with only a few candidates realising that aluminium had lost electrons and had therefore been oxidised and even fewer realising that the nitrite/nitrite was being reduced.

(c)(i)-(iii) Very few candidates correctly stated that iodine was produced in (ii) and therefore even fewer went on to suggest the use of starch as a confirmatory test in (iii).

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Paper 9701/41
A Level Structured Questions

Key messages

- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out and never overwritten with the new answer.
- On a chemistry paper it is essential for an Examiner to be able to read the chemical symbols, the subscripts used in formulae and the charges of ions.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.

General comments

Candidates who had prepared well for the examination were able to attempt all questions. Many candidates were able to work through to the end of the paper, with very few blank responses seen.

Comments on specific questions

Question 1

- (a) Many candidates gave the correct answer. Common errors were Sn for the $\text{Sn}^{4+}/\text{Sn}^{2+}$ half-cell, and Pt for Al^{3+}/Al half-cell.
- (b)(i) Many incorrect versions of the Nernst equation were suggested. All correct variants of this equation were credited, for example $E = E^\ominus + 0.059/z \log(\text{ox})/(\text{red})$, and $E = E^\ominus + RT/nF \ln(\text{ox})/(\text{red})$. Some candidates used an incorrect value for their E^\ominus or the number of electrons.
- (ii) This was generally answered well. A common mistake was to use 0.15 instead of their answer from (b)(i).
- (iii) Many fully correct answers were seen.
- (c) Many candidates answered this well. Common errors were $1.01 \times 10^5 \text{ g}$ (no multiplication by 24), $7.25 \times 10^6 \text{ g}$ (no division by 3), use of incorrect significant figures in their final answer or the units used for their value.
- (d) This proved difficult for many candidates. They needed to suggest why H_2 was formed in preference to Cr metal at the negative electrode. The value for the H_2/H^+ electrode was frequently omitted and many just compared the Cr^{2+}/Cr half-cell with $\text{SO}_4^{2-}/\text{SO}_2$ half-cell potential.

Question 2

- (a) Many candidates had incorrect diagrams with an extended octet of ten electrons around the central nitrogen atom; these did not gain credit.
- (b) (i) This was well known.
(ii) This question was usually fully credited.
(iii) This question was found to be very difficult by most candidates. They had to link the stoichiometry in the overall equation to the individual orders in the rate equation.
- (c) (i) This was often correct. Common errors included drawing a curve, a straight line with a positive gradient or having an incorrect final ($CINO_2$).
(ii) This question was usually answered well.
(iii) Many candidates recognised that the reaction had reached equilibrium. A common error was stating that one of the reactants had run out.

Question 3

- (a) Most candidates gave a correct answer.
- (b) This was generally well answered. Common errors were:
- stating a change in state from liquid to solid for water cooling from $80^\circ C$ to $60^\circ C$
 - stating that the $CaCl_2$ reacted with water, or a change in state from solid to liquid had occurred
 - stating that gas molecules were being converted into a solid for the lattice energy of $CaCl_2$.
- (c) (i) This was rarely awarded. Most candidates omitted 'change' in their answer.
(ii) Most candidates gave a correct equation for ΔG ; fewer could rearrange this equation or explain how to use it to obtain the decomposition temperature.

Question 4

- (a) Most candidates gave a correct answer. Some incorrectly suggested chloroethane or omitted a halogen carrier such as $AlCl_3$.
- (b) This was usually answered well. Common errors included:
- chlorination of the benzene ring
 - nitration at the 2- or 4-position, or di-substitution of the benzene ring
 - a reaction occurred; the bromination of the benzene ring.
- (c) (i) Most candidates gave a correct answer.
(ii) Better performing candidates could recall the electrophilic substitution mechanism.
Common errors included:
- the curly arrow did not go from the carbon atom (of the CN^-) to the carbon atom in aldehyde group
 - the lone pair on the CN^- or the O^- in the intermediate were often omitted
 - the partial charges on the $C=O$ bond were often omitted
 - the intermediate had a trivalent carbon atom (a $C-H$ bond being omitted)
 - the mechanism did not show the catalytic role of the CN^- ions; $H-CN$ was not used in the step 2 of the mechanism.
- (d) (i) This question was generally answered well.
(ii) This answer was usually correct.
(iii) Many candidates gave a correct answer. A common error was omitting 'concentrated' with H_2SO_4 .

- (iv) This was generally well answered. Common errors were three or five peaks.
- (v) The incorrect ranges 0–50 and 10–40 were regularly seen.

Question 5

- (a) (i) Most candidates gave the correct K_{sp} expression.
- (ii) Many candidates correctly calculated a value for K_{sp} . A common error was to omit the 2^2 (= 4) in the calculation for the $(Ag^+)^2$.
- (iii) This was generally well answered. Most candidates correctly calculated the moles of Ag_2S . A common error was 0.097 dm^3 (multiplying 0.00403 by 24).
- (b) (i) This was answered well by the majority of candidates. The link between pH and (H^+) and the use of the K_a expression to find the value of pH was generally well understood.
- (ii) Many candidates found this question very difficult. Many candidates were unable to calculate the equilibrium concentrations of $(HOBr)$ and (BrO^-) . The most common error was 8.10 from $HOBr$ is 4.0×10^{-3} and BrO^- is 1.0×10^{-3} .

Question 6

- (a) (i) This was generally well answered. A common error was the use of $Mg(s)$ as the reactant.
- (ii) This proved difficult for some candidates. Many omitted state symbols in their answer or formed SrO instead of $Sr(OH)_2$ as a product.
- (iii) Most candidates knew that the reactivity increased down the group but often did not sufficiently explain their reasoning in terms of the increasing ease of losing electrons.
- (b) (i) Most candidates answered this well.
- (ii) This was well known.
- (iii) Most candidates had prepared well on this topic. Many correctly stated that the stability and the cation radius increases down Group 2. Less polarisation of the nitrate anion was less frequently seen. Some candidates incorrectly suggested there was polarisation of the cation.
- (c) The trend and its explanation were well understood by candidates. It was common to see a statement regarding decreasing solubility due to ΔH_{latt} and ΔH_{hyd} decreasing down Group 2. The decrease in ΔH_{hyd} is more and the ΔH_{sol} becomes more endothermic were less frequently seen.

Question 7

- (a) Many candidates understood the idea of a transition element, but some definitions often lacked precision.
- (b) (i) Common errors were showing one or both colour changes reversed.
- (ii) This question was generally answered well.
- (c) (i) This question was often found difficult, in particular many candidates did not specify the bonding to the metal atom/ion.
- (ii) Most candidates answered this correctly. However, the overall charge was frequently answered incorrectly.

- (iii) This was answered well by many candidates. The most common errors were:
- diagrams not showing the Ru being bonded to sulfur atom of SO_2
 - diagrams without any 3-D bonds
 - diagrams in which 3-D bonds were drawn but where the complex could not be octahedral.
- (iv) Most candidates recognised geometrical isomerism. Optical was a common incorrect answer.
- (v) Many fully correct answers were seen. A common error was not mentioning that d orbitals were split.

Question 8

- (a) (i) Common errors included the omission of heat or aqueous conditions.
- (ii) Most candidates hydrolysed the triester correctly but did not show their amino acids in the correct ionised form for the conditions chosen in (a)(i).
- (b) Common errors included:
- stating an incorrect type of force such as peptide bonds or covalent bonds
 - stating individual atoms as a pair of groups.
- (c) (i) Most candidates gave a correct answer.
- (ii) Candidates did not perform well on this question. Only a small number of candidates gained full credit. Ethanoic acid and ethanol are two incorrect answers that were regularly seen. Where the structures were correct, the names were often incorrect for example diethanoic acid and diethanol.

Question 9

- (a) (i) This question was generally answered well. A common error was the omission of the counterion Cl^- with $\text{HCl}(\text{aq})$.
- (ii) Many good, clearly explained answers were seen. The most common error being the omission of 'lone pair' with electrons.
- (b) Many diagrams were well drawn. Common errors included:
- monobromination of the benzene ring or bromination at 3- and 5-positions
 - the positive charge on the terminal nitrogen for the diazonium salt $\text{R-N}\equiv\text{N}^+$
 - formation of sodium butoxide instead of butan-1-ol.
- (c) (i) Candidates did not perform well on this question. Many suggested three or four peaks, rather than two peaks.
- (ii) This question was found to be very difficult. Many candidates did not follow the guidance in the stem to circle the protons responsible for the peaks in (c)(i), for example, the carbon atom of the respective group, or a single H in a particular group only being circled.
- (iii) This was answered well by many candidates. The commonest error was to omit any explanation about proton exchange between the NH_2 and D.
- (d) Many candidates could identify the fragments. The most common error was $\text{C}_6\text{H}_6\text{N}^+$.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

- Better performing candidates wrote legibly and paid particular attention to the clarity of their writing in the formulae of compounds or the charges on ions.
- Crossing out and overwriting so that, for example, a 2 and a 3 in a formula are both still visible and legible, is ambiguous and credit cannot be awarded. If a candidate wishes to change an answer, this should be crossed out thoroughly and then rewritten afterwards in another space. Blank space on the question paper or a continuation sheet can be used to rewrite an answer. Candidates must clearly identify the question number of this is necessary.
- Where a question asks for a comparison of the properties of two substances or ions, candidates should always make it very clear which of the two they are describing in each part of their answer. The use of the word 'it' should be strongly discouraged in such answers.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.

General comments

Many very good responses and a significant number of excellent ones were seen. Many candidates were able to work through to the end of the paper, with very few blank responses seen.

Comments on specific questions

Question 1

- (a) This was answered correctly by the majority of candidates.
- (b) (i) Candidates found this a very challenging question, both in chemical and mathematical level of demand.
- (ii) Many candidates did not realise that they had to use +1.07 V and their answer to (i) in order to answer this question.
- (iii) Most candidates were able to deduce the identities of the oxidising agent and of the reducing agent and were able to balance the equation.
- (c) Many excellent answers to this calculation were seen, including many different approaches. The methods of better performing candidates were clearly explained. The commonest sources of errors were included:
- calculations that stopped after reaching 16 200 C and 0.0802 mol Cu
 - use of the value 96 500 C from the Data Booklet and therefore calculating 6.03×10^{23}
 - use of the value 6.03×10^{23} from the Data Booklet.
- (d) Some excellent answers were seen which explained, using E^\ominus values, why hydrogen is given off at the cathode. Many answers focused on the presence of the sulfate ion, but as this ion is negatively charged it will not be involved in the formation (or otherwise) of magnesium.

Question 2

- (a) This was answered well. Some candidates did not specify what is being halved when explaining the half-life of a reaction. Better responses included the phrase 'the amount of reactant' in their responses; other candidates omitted the expression 'time taken'. Explanations of the rate-determining step were usually correct.
- (b) Many candidates found this very difficult; although some excellent scripts were seen. The importance of temperature control, and the use of a large excess of the other reactant, were very rarely referred to.
- (c) This was answered well.

Question 3

- (a) (i) Most candidates could calculate the correct concentration.
- (ii) This was usually done well. A significant number of candidates calculated K_a but did not go on to calculate pK_a .
- (b) (i)(ii) Ionic equations were used to answer the questions most successfully, but molecular equations were also acceptable. Some equations were not balanced for charge, or for substances, or for both.
- (c) (i) Most candidates could do this successfully; others did not show their working, which was a requirement of the question.
- (ii) Some calculations included rounding errors. Some candidates did not realise that $(H^+) = (OH^-)$.

Question 4

- (a) The correct answer was seen on most scripts. The small number of errors were mostly stoichiometry; a very small number of algebraic errors were also seen.
- (b) Candidates are strongly advised to use the Gibbs equation to answer a question such as this. Candidates who used $\Delta S_{total} = \Delta S_{surroundings} + \Delta S_{system}$ almost without exception became confused and performed poorly.
- (c) The key factor in the explanation was the decrease in the number of moles of gas present.

Question 5

- (a) The flame colours were not well known. The flame colour of strontium was sometimes confused with the flame colour of calcium. Not all candidates mentioned the formation of a white solid product in each case.
- (b) (i) Full credit was often awarded here. A number of equations for the decomposition of $CaCO_3$ incorrectly included O_2 in either the reactants or the products.
- (ii) A precise statement, such as 'to raise pH' or 'to neutralise acidic soil' was often seen. No credit could be awarded for a vague statement such as 'to control pH'.
- (iii) This explanation was well known and clearly described by many candidates.
- (c) Commonly seen incorrect statements included:
- $NaOH(aq)$ and $BaCl_2(aq)$ produce a white precipitate
 - steamy fumes of HCl are seen when $H_2SO_4(aq)$ and $BaCl_2(aq)$ are mixed.
- (d) This explanation was well known and clearly described by many candidates.

Question 6

- (a) This definition was well known.
- (b) Some candidates were able to describe the observations; fewer gave correct formulae. It was common to see an incorrect formula such as $(\text{Cu}(\text{NH}_3)_2(\text{H}_2\text{O})_4)^{2+}$ after a few drops of dilute ammonia and an incorrect formula such as $(\text{Cu}(\text{NH}_3)_6)^{2+}$ after an excess of dilute ammonia.
- (c) This proved to be one of the most difficult questions on the paper to many candidates. A large number of answers explained the origin of colour in a solution of $\text{Cu}^{2+}(\text{aq})$. These answers did not answer the question, which was about the *change* in colour during the process described. However, some excellent answers were seen in which ligand exchange, the consequent change in ΔE value and the consequent change in the frequency or wavelength of light absorbed were all clearly described.
- (d) Many candidates incorrectly focused on the presence of sulfate ions. Candidates who realised that this is a redox reaction often quoted the necessary data and were able to write a balanced equation.
- (e) (i) Some responses included ionic charges are written outside the final set of square brackets.
(ii) The majority of candidates were able to calculate the correct answer here.

Question 7

- (a) (i) This was answered well. Some incorrect linkages and ring orientations were seen and some candidates ignored the instruction to 'include two repeat units'.
(ii) Many candidates placed more than one tick in the table and so credit could not be awarded.
(iii) Many candidates knew that a polyamide is biodegradable; a smaller number knew that this is due to hydrolysis.
(iv) This was answered well.
(v) This was answered well. Some responses did not state that the acids used in step 1 must be concentrated.
- (b) (i) Some candidates were able to describe each of three terms; others need more practice recalling these standard definitions.
(ii) Most candidates correctly stated amide or peptide bonds.
(iii) Many candidates knew the answer was hydrogen bonding; a smaller number described clearly the groups of atoms involved. Better performing candidates stated, 'from the H on N-H to the O of C=O'. A significant number of candidates wrote 'from COOH to NH₂' and did not gain credit.

Question 8

- (a) This was answered well by many; others, incorrectly, said that the bromine should be aqueous..
- (b) Many candidates knew which compound was being described and could use the correct conventions to name it. Some candidates did not read the question and answered 'HBr'.
- (c) The importance of adding nitrile groups to extend the carbon chain was only appreciated by a minority of candidates.
- (d) The reagents and conditions were correctly stated by some candidates.
- (e) (i) This was well known.
(ii) This was not well known. A number of answers incorrectly suggested compounds that could only be obtained by reduction of ethanedioic acid.

- (f) Many candidates found it difficult to gain credit here. Those who did well usually focused on either the strength of the O-H bond, or the stability of the anion formed.
- (g) (i) It was common for the peak at δ 12.7 to be identified. Some candidates were not sufficiently specific; stating 'alkane' does not distinguish between the CH proton and the CH₃ protons.
- (ii) Most candidates' answers included 'quartet' or 'quadruplet'. Credit was not awarded for 'three neighbouring hydrogen atoms'; 'three hydrogen atoms on the neighbouring carbon atom' was acceptable.
- (iii) This was often answered well.

Question 9

- (a) (i) This was found to be difficult.
- (ii) This was found to be very difficult. The question states that 'the two electrons in the lone pair on the nitrogen atom of the amide group' become part of the single delocalised system. Better performing candidates deduced that the NH₂ group must be planar with a bond angle close to 120°.
- (b) (i) Some candidates could correctly draw the structural formula of **E**.
- (ii) If candidates stated 'aqueous ammonia' or 'ethanolic ammonia' is used, the solution should have been described as concentrated. This would minimise the formation of other products.
- (c) This was found to be difficult. The two compounds were the products of acidic and alkaline hydrolysis of the amide.
- (d) (i) This was usually answered well.
- (ii) Many candidates found it difficult to gain full credit. Better performing candidates focused on the lone pairs on the nitrogen atoms and whether neighbouring groups would donate or remove electron density from those lone pairs. Some candidates believed phenylamine and C₆H₅NH₂ to be two separate compounds.
- (e) This question asked for the peak height to be calculated from the number of carbon atoms rather than the other way round; many candidates answered it well. Some candidates wrongly deduced that there are either five or seven carbon atoms in a nicotinamide molecule.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out and never overwritten with the new answer.
- On a chemistry paper it is essential for an Examiner to be able to read the chemical symbols, the subscripts used in formulae and the charges of ions.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.

General comments

Candidates who had prepared well for the examination were able to attempt all questions. Many candidates were able to work through to the end of the paper, with very few blank responses seen.

Comments on specific questions

Question 1

- (a) Many candidates gave the correct answer. Common errors were Sn for the $\text{Sn}^{4+}/\text{Sn}^{2+}$ half-cell, and Pt for Al^{3+}/Al half-cell.
- (b)(i) Many incorrect versions of the Nernst equation were suggested. All correct variants of this equation were credited, for example $E = E^\ominus + 0.059/z \log(\text{ox})/(\text{red})$, and $E = E^\ominus + RT/nF \ln(\text{ox})/(\text{red})$. Some candidates used an incorrect value for their E^\ominus or the number of electrons.
- (ii) This was generally answered well. A common mistake was to use 0.15 instead of their answer from (b)(i).
- (iii) Many fully correct answers were seen.
- (c) Many candidates answered this well. Common errors were $1.01 \times 10^5 \text{g}$ (no multiplication by 24), $7.25 \times 10^6 \text{g}$ (no division by 3), use of incorrect significant figures in their final answer or the units used for their value.
- (d) This proved difficult for many candidates. They needed to suggest why H_2 was formed in preference to Cr metal at the negative electrode. The value for the H_2/H^+ electrode was frequently omitted and many just compared the Cr^{2+}/Cr half-cell with $\text{SO}_4^{2-}/\text{SO}_2$ half-cell potential.

Question 2

- (a) Many candidates had incorrect diagrams with an extended octet of ten electrons around the central nitrogen atom; these did not gain credit.
- (b) (i) This was well known.
(ii) This question was usually fully credited.
(iii) This question was found to be very difficult by most candidates. They had to link the stoichiometry in the overall equation to the individual orders in the rate equation.
- (c) (i) This was often correct. Common errors included drawing a curve, a straight line with a positive gradient or having an incorrect final ($CINO_2$).
(ii) This question was usually answered well.
(iii) Many candidates recognised that the reaction had reached equilibrium. A common error was stating that one of the reactants had run out.

Question 3

- (a) Most candidates gave a correct answer.
- (b) This was generally well answered. Common errors were:
- stating a change in state from liquid to solid for water cooling from $80^\circ C$ to $60^\circ C$
 - stating that the $CaCl_2$ reacted with water, or a change in state from solid to liquid had occurred
 - stating that gas molecules were being converted into a solid for the lattice energy of $CaCl_2$.
- (c) (i) This was rarely awarded. Most candidates omitted 'change' in their answer.
(ii) Most candidates gave a correct equation for ΔG ; fewer could rearrange this equation or explain how to use it to obtain the decomposition temperature.

Question 4

- (a) Most candidates gave a correct answer. Some incorrectly suggested chloroethane or omitted a halogen carrier such as $AlCl_3$.
- (b) This was usually answered well. Common errors included:
- chlorination of the benzene ring
 - nitration at the 2- or 4-position, or di-substitution of the benzene ring
 - a reaction occurred; the bromination of the benzene ring.
- (c) (i) Most candidates gave a correct answer.
(ii) Better performing candidates could recall the electrophilic substitution mechanism.
Common errors included:
- the curly arrow did not go from the carbon atom (of the CN^-) to the carbon atom in aldehyde group
 - the lone pair on the CN^- or the O^- in the intermediate were often omitted
 - the partial charges on the $C=O$ bond were often omitted
 - the intermediate had a trivalent carbon atom (a $C-H$ bond being omitted)
 - the mechanism did not show the catalytic role of the CN^- ions; $H-CN$ was not used in the step 2 of the mechanism.
- (d) (i) This question was generally answered well.
(ii) This answer was usually correct.
(iii) Many candidates gave a correct answer. A common error was omitting 'concentrated' with H_2SO_4 .

- (iv) This was generally well answered. Common errors were three or five peaks.
- (v) The incorrect ranges 0–50 and 10–40 were regularly seen.

Question 5

- (a) (i) Most candidates gave the correct K_{sp} expression.
- (ii) Many candidates correctly calculated a value for K_{sp} . A common error was to omit the 2^2 (= 4) in the calculation for the $(Ag^+)^2$.
- (iii) This was generally well answered. Most candidates correctly calculated the moles of Ag_2S . A common error was 0.097 dm^3 (multiplying 0.00403 by 24).
- (b) (i) This was answered well by the majority of candidates. The link between pH and (H^+) and the use of the K_a expression to find the value of pH was generally well understood.
- (ii) Many candidates found this question very difficult. Many candidates were unable to calculate the equilibrium concentrations of $(HOBr)$ and (BrO^-) . The most common error was 8.10 from $HOBr$ is 4.0×10^{-3} and BrO^- is 1.0×10^{-3} .

Question 6

- (a) (i) This was generally well answered. A common error was the use of $Mg(s)$ as the reactant.
- (ii) This proved difficult for some candidates. Many omitted state symbols in their answer or formed SrO instead of $Sr(OH)_2$ as a product.
- (iii) Most candidates knew that the reactivity increased down the group but often did not sufficiently explain their reasoning in terms of the increasing ease of losing electrons.
- (b) (i) Most candidates answered this well.
- (ii) This was well known.
- (iii) Most candidates had prepared well on this topic. Many correctly stated that the stability and the cation radius increases down Group 2. Less polarisation of the nitrate anion was less frequently seen. Some candidates incorrectly suggested there was polarisation of the cation.
- (c) The trend and its explanation were well understood by candidates. It was common to see a statement regarding decreasing solubility due to ΔH_{latt} and ΔH_{hyd} decreasing down Group 2. The decrease in ΔH_{hyd} is more and the ΔH_{sol} becomes more endothermic were less frequently seen.

Question 7

- (a) Many candidates understood the idea of a transition element, but some definitions often lacked precision.
- (b) (i) Common errors were showing one or both colour changes reversed.
- (ii) This question was generally answered well.
- (c) (i) This question was often found difficult, in particular many candidates did not specify the bonding to the metal atom/ion.
- (ii) Most candidates answered this correctly. However, the overall charge was frequently answered incorrectly.

- (iii) This was answered well by many candidates. The most common errors were:
- diagrams not showing the Ru being bonded to sulfur atom of SO_2
 - diagrams without any 3-D bonds
 - diagrams in which 3-D bonds were drawn but where the complex could not be octahedral.
- (iv) Most candidates recognised geometrical isomerism. Optical was a common incorrect answer.
- (v) Many fully correct answers were seen. A common error was not mentioning that d orbitals were split.

Question 8

- (a) (i) Common errors included the omission of heat or aqueous conditions.
- (ii) Most candidates hydrolysed the triester correctly but did not show their amino acids in the correct ionised form for the conditions chosen in (a)(i).
- (b) Common errors included:
- stating an incorrect type of force such as peptide bonds or covalent bonds
 - stating individual atoms as a pair of groups.
- (c) (i) Most candidates gave a correct answer.
- (ii) Candidates did not perform well on this question. Only a small number of candidates gained full credit. Ethanoic acid and ethanol are two incorrect answers that were regularly seen. Where the structures were correct, the names were often incorrect for example diethanoic acid and diethanol.

Question 9

- (a) (i) This question was generally answered well. A common error was the omission of the counterion Cl^- with $\text{HCl}(\text{aq})$.
- (ii) Many good, clearly explained answers were seen. The most common error being the omission of 'lone pair' with electrons.
- (b) Many diagrams were well drawn. Common errors included:
- monobromination of the benzene ring or bromination at 3- and 5-positions
 - the positive charge on the terminal nitrogen for the diazonium salt $\text{R-N}\equiv\text{N}^+$
 - formation of sodium butoxide instead of butan-1-ol.
- (c) (i) Candidates did not perform well on this question. Many suggested three or four peaks, rather than two peaks.
- (ii) This question was found to be very difficult. Many candidates did not follow the guidance in the stem to circle the protons responsible for the peaks in (c)(i), for example, the carbon atom of the respective group, or a single H in a particular group only being circled.
- (iii) This was answered well by many candidates. The commonest error was to omit any explanation about proton exchange between the NH_2 and D.
- (d) Many candidates could identify the fragments. The most common error was $\text{C}_6\text{H}_6\text{N}^+$.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- Better performing candidates set out calculations in a logical sequence.
- In calculations, candidates are advised to carry through intermediate values held on their calculators, thus avoiding approximating divergence.
- List answers often contain contradictions or errors and should be avoided.

General comments

There was a tendency to over approximate during the course of a calculation. Internal approximation usually leads to an increase in the divergence of a candidate's result from the actual answer. This is particularly significant in multistage calculations such as **Question 1(a)(i)**, where 0.003 was often used for 0.00332.

There was a difference in success between numerical and chemical questions; the table data calculations were answered better than the textual chemical questions.

The basis for this examination is experimental investigation, however, there is a need for basic chemical knowledge. This was displayed in **Question 1(b)**, where candidates had difficulty with redox; a significant number of candidates did not understand the reaction to be $2\text{Cu}^{2+} + 4\text{I}^- \rightarrow \text{I}_2 + 2\text{CuI}$ and stated incorrectly that no I_2 would be formed. Also, H^+ in **Question 1(b)(ii)** was commonly incorrectly considered to be reduced in the reaction.

Candidates should be encouraged to consider their responses in order to avoid non-specific responses. Answers such as '*the time was recorded wrongly*', '*the temperature of the solution was not 25 °C*' and '*the timer was started and stopped too early*', in **Question 2(e)** illustrate this.

The tendency to over-answer was present, perhaps in the hope of multiple answers providing something being correct; this approach is almost certain to fail. The danger to the candidate is that numerous answers often contradict each other. For example, in **Question 1(d)(i)**:

*'The time taken was longer
because the molecules are closer together
so the intermolecular forces are greater
thus the viscosity decreased.'*

This response shows how the final, incorrect, response contradicts and negates the previous two correct statements.

Comments on specific questions

Question 1

- (a) (i) Many candidates were able to successfully transfer their experience into a novel situation. Most candidates correctly calculated the moles of Y_2O_3 and applied that properly, along with stoichiometric ratio of 1:4:6 and M_r to $BaCO_3$ and CuO . A common error was to use an incorrect stoichiometric ratio, such as 1:2:3; others wrongly applied the 0.750 g to $YBa_2Cu_3O_7$.

A significant number of candidates used inappropriate rounding; this affected their calculated values for $BaCO_3$ and CuO . The moles of Y_2O_3 of 3.32×10^{-3} were often rounded to 3×10^{-3} , which produced about a 10 percent difference in the final answers. Other inappropriate rounding was the 0.0132 moles of $BaCO_3$ to 0.013 and the 0.0199 to 0.02 moles, which introduced further deviation. Often candidates wrote a rounded value in their calculation but used a retained calculator value in subsequent calculations; it is inappropriate to see intermediate values given to one significant figure with final values given to more significant figures.

Candidates should be advised never to approximate, round or truncate intermediate calculation values.

- (ii) This straightforward question was rarely answered successfully. Some, incorrectly, suggested dissolving the compound in water and filtering; others just weighing or reheating or putting the solid in a sealed container to prevent the solid from coming in contact with oxygen or carbon dioxide. A significant number of candidates did not realise that the purpose of heating/weighing to constant mass was to maximise yield in a reaction that produced a gas. Many candidates erroneously assumed that the procedure was to remove water, presumably because heating to constant mass is a procedure that is often applied to drying. These candidates answered the question out of context. Indeed, the provided reaction equation clearly shows that no water was produced.

It is appropriate to remind candidates to read the question properly and answer the question asked and not the one that they assumed they were asked.

- (b) (i) Candidates found this a difficult question with many showing confusion over redox. This question was often over-answered, usually with conflicting answers leading to no credit. A standard correct response was 'the Cu^{2+} would react with the I^- to make CuI ' on the basis that I_2 is added in step 3 following no removal of Cu^{2+} in step 2. Unfortunately, this was often followed with 'this means that no I^- would be available for Br_3^- in step 3' or 'when Cu^{2+} reacts with I^- no I_2 will be formed'. These additional incorrect responses negated any correct response.

In the first case, step 3 clearly states 'Excess I^- is added ...' so the reasoning is invalid. In the second case, the I^- that reacts with the Cu^{2+} is oxidised, as shown by the first item of data, to produce I_2 , so instead of no I_2 being produced, in fact more I_2 would be produced. Many candidates quoted the Cu^{2+}/CuI half equation but did not link it to the I_2/I^- half equation so missed the link between oxidation and reduction. Throughout this question, there was confusion over the roles of the reagents with Cu^{2+} and/or I^- being described as an oxidising agent or reducing agent.

Candidates should be advised to avoid over answering with multiple responses, which often contain incorrect statements and negates any correct response.

- (ii) This question was less well answered than (b)(i). A common incorrect response was that ' H^+ reacted with the I^- '. Very few candidates understood that the iodide ions would be oxidised in acid solution. Others suggested that removal of the hydrogen ion was essential to prevent a reaction with the sodium thiosulfate. Very few candidates referred to the final item of data, which clearly shows O_2 being reduced in the presence of H^+ . H^+ was often considered to be an oxidising agent rather than its role in the equation of producing water.

The responses in (b)(i) and (b)(ii) demonstrated a lack of familiarity with redox and redox potentials and not linking two redox half reactions together. Only a handful of candidates properly combined two half equations to give a feasible redox.

- (iii) The vast majority of candidates were successful with this calculation.

- (c) (i) Virtually all candidates answered this correctly.
- (ii) Many candidates were not entirely successful in answering this question. The basic answer starts with dissolving the solid in the beaker in distilled water, transferring the solution to a 250 cm³ volumetric flask, rinsing the beaker and putting the rinsings into the volumetric flask and finally making up to the mark. The most common omission was failing to mention rinsing the beaker and transferring these rinsings. Many did not make the solution in the beaker but placed the solid directly into the volumetric flask, whilst others thought the citrate was a solution. Often, some candidates transferred the solution in the beaker using pipettes, measuring cylinders or even burettes, all of which are inappropriate.
- (d) The objective to achieve concordancy across at least two values was understood by most candidates. Recognition of the lack of concordancy and the need to repeat titrations until concordancy was achieved gained full credit. Some candidates erroneously considered that the burette should be reset to 0.00 cm³. Suggestions of method improvements, such as adding dropwise as the end point was approached to make concordancy more likely, were credited. A few candidates thought, incorrectly, the iodine solution was in the burette.

Question 2

- (a) Removing acids with water and the subsequent drying with a volatile liquid such as propanone is a standard technique. The key requirement for this question was that firstly acid, then secondly, water was removed from the viscometer. Popular incorrect responses included dilution (rather than removal) and removal of (unspecified) impurities.
- (b) The calculation of the table data was generally correct. There were very few calculation or rounding errors. Observed errors in column 6 were stating 0.0220 for 0.0221 and 0.0239 for 0.0240. The majority of observed errors were not giving the values to three significant figures or quoting fractions in column 1. Some candidates gave the results in column 6 to two decimal places rather than three significant figures. Quoting values to two decimal places in column 6 resulted in only two values, 0.02 and 0.03, which then presented difficulties in plotting the graph.
- (c) The plotting of the data was virtually without fault. Furthermore, virtually all candidates presented a good line of best fit through the data.
- (d) (i) Most candidates understood that the time taken would be greater, but many did not give an adequate explanation. These candidates seemed to be more concerned with the kinetic energy/speed of the molecules rather than the viscosity of the solution. A significant number of candidates who correctly answered that time would be greater, then contradicted themselves by concluding that viscosity decreased.
- (ii) Many candidates suggested a water-bath but failed to suggest any form temperature regulation for the water-bath. Some candidates suggested a temperature-controlled room or an incubator; neither would be practical in this context.
- (e) Virtually all candidates correctly identified the anomalous result. Even though the question stated the concentration of the solution was correct, a few candidates stated that the concentration here was higher/lower. Candidate over-answering caused some problems here.
- (f) (i) The initial requirement was to extrapolate the line back to read the intercept at $c = 0$ which most, but not all, candidates managed.
- (ii) This question was generally answered correctly with candidates being able to manipulate log calculations successfully. A small number did not antilog their calculated value and some used log to base e in either or both log operations.
- (iii) The question required division of the previously calculated M_r by the M_r of phenylethene (104). A small number of candidates did not use the correct M_r of phenylethene. The majority of candidates stated a whole number but sometimes with a rounding error.
- (g) Most candidates realised that the value of 'a' would be higher for poly(ethanol) dissolved in water. However, the explanation was not always adequate or clearly stated. Many understood that hydrogen bonds would be made between the poly(ethanol) and water but did not state that these

bonds were stronger than the intermolecular bonds between the poly(phenylethene) and methylbenzene.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- Centres should include as much practical work as possible in their course so that candidates are familiar with common experimental techniques and apparatus even if unusual chemicals, such as in **Question 1**, are used. It was apparent that many candidates could not provide suitable details of condensers in **Question 1(a)(i)**; knowledge about the key points of reflux was weak in **Question 1(a)(ii)-(iv)**; the required apparatus for distillation in **Question 1(b)(i)** was frequently unworkable.
- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures.
- Candidates should be dissuaded from offering lists of answers beyond the number of responses asked for. **Question 1(d)** required two reasons why CH_3I was the preferred halogenoalkane and correct answers were often contradicted by inclusion of a third, and sometimes fourth, incorrect reason.
- Candidates should be aware that lines of best fit need to split the plotted points in such a way as to have an approximately equal number of points (excluding anomalies) either side of the line. Drawing a line from the origin to the last point may not necessarily result in this outcome.
- If a candidate considers a point on a graph to be anomalous then it should be circled, whether this is required or not. This would help Examiners appreciate why points may have been ignored when drawing a line of best fit.

General comments

Question 2 had multi-step calculations. It is important that candidates do not round in early steps of a calculation. Rounding should be done to the required number of significant figures after calculating the final answer.

Question 2 involved graph work. Candidates are advised to clearly show their points by using a diagonal cross, 'x', with the intersect of the lines being the exact co-ordinates on the grid. Alternatively, a point within a circle, \odot , would be suitable with the point being the exact co-ordinates on the grid. Candidates should be aware that a single point (with no circle) will likely not show up if a line of best fit needs to be drawn over it.

Comments on specific questions

Question 1

- (a) (i) Many candidates were not aware that cooling water always enters a condenser via the lower inlet, whether this is for a reflux set-up or for distillation. The reason for having cooling water enter the lower inlet is to ensure the central tube is always surrounded by cold water.

Many candidates seemed unaware of this basic A level apparatus set-up, which might suggest that these candidates had not seen an experiment involving a reflux set-up.

- (ii) Many candidates correctly suggested either drop-by-drop addition of the solution or using an external cooling bath as a measure of controlling a very exothermic reaction. A common misconception was to use anti-bump granules to reduce temperature rise.

- (iii) Most candidates were not familiar with the idea of why a reflux apparatus set-up is used. It is used to prevent volatile vapours escaping from the reaction mixture. This is done by condensing the volatile vapours and allowing them to run back into the flask. The question asked candidates to consider responses which did not relate to increasing the rate of reaction; a point many candidates overlooked.
- (iv) The fact that most candidates thought that placing a bung in the top of the condenser was an improvement, reinforced the idea that candidates were unfamiliar with a reflux set-up. A relative few realised that pressure would build up, causing the apparatus to 'pop apart' or 'explode'.

Some candidates thought using a bung deliberately to increase the pressure would beneficially either increase the rate of reaction or favour the equilibrium yield.

- (b) (i) It was expected that candidates would draw a condenser in the diagonal 'distillation' position and draw the system sealed, except for the delivery end of the condenser.

Many drew a condenser attached to the flask neck which originally held the tap funnel or drew condensers receiving vapours at a lower point than they would leave. Thus, any vapours going into such a condenser would simply condense and run back into the mixture rather than distilling over.

- (ii) This data-based question was correctly answered by most candidates. The key point was that ethanol had a lower boiling point than the other two substances (or the lowest), rather than just a low boiling point.
- (iii) Many candidates misunderstood this relatively simple question. Candidates were told 4-aminobenzaldehyde is soluble in hot water, but not in cold water. From previous parts, they would have been aware that the solution also contained aqueous inorganic substances.

It was expected that candidates would cool the solution, then filter the cold solution, making sure the residue was rinsed with (cold) water to remove any inorganic impurities.

Many misinterpreted the question and treated it as a purification by recrystallisation process. Many others simply crystallised by heating to dryness; others suggested evaporating the product or heating to constant mass.

- (c) Very few candidates realised that under acidic conditions 4-aminobenzaldehyde forms a dimer type product in a condensation reaction and that the loss of water meant the mass of the dimer molecule would be less than the two molecules of 4-aminobenzaldehyde due to the loss of water.

Most struggled to give plausible responses.

- (d) This simple data handling question was poorly addressed. Very few candidates realised that the **lowest** carbon-halogen bond energy of CH_3I would mean a quicker rate of reaction, in comparison to the other two halogenoalkanes. Even fewer realised that a boiling point of 43°C meant that CH_3I would be a **liquid** at room temp whereas the other two boiling points (4°C and -97°C) meant the other two compounds would be gaseous.

Question 2

- (a) (i) The majority of candidates answered this calculation correctly.
- (ii) Most candidates could do the calculations; a lack of correct rounding and incorrect use of significant figures caused some to unnecessarily lose marks.
- (b) Most plotting was quite good, as were the straight lines of best fit. Some candidates relied on drawing a line of best fit by connecting first to last points; this method often results in credit being lost, unless the line gives equal numbers of points on each side of the line.

- (c) (i)** Most candidates could read the coordinates correctly; some were troubled by the difficult x -axis scale. A few did not know the (x, y) convention and others did not allow a sufficient range of values.
- Most candidates did not realise that the x -axis had a scale involving 10^{-3} and omitted this from their calculations of the gradient.
- (ii)** This was a challenging calculation, which involved deducing an answer based upon the response given in **(c)(i)**. The most common error was to calculate an answer in J rather than converting the value to kJ.
- (d) (i)** This question was designed to find out if candidates could use their graph to determine the reliability of the experiment. Candidates who performed less well suggested generic answers, such as a lack of repeat experiments. Better performing candidates based their responses on the relationship of plotted points to the line of best fit; some said that their points were all near their line of best fit when they clearly were not.
- (ii)** Many candidates did not understand that they had to calculate two values to provide a range for the enthalpy change for fusion from the literature values. Many who attempted these calculations often went wrong.
- Relatively few interpreted the question fully and often did not provide the essential comment about the accuracy of the value determined from the experimental procedure compared to the calculated range.
- (e)** Many did not appreciate that the use of the Hess cycle given in the question was the route to the answer. Where candidates did use the Hess cycle to determine answers, they did not address possible changes in an enthalpy value in expected terms such as 'more positive' or 'less negative'. 'Bigger' or 'higher' or 'lower' or 'less' do not convey the direction of an enthalpy change.
- (f) (i)** Most candidates secured the mark; some erroneously suggested the number of moles of naphthalene was changing.
- (ii)** The relationship, involving logs, negatives and division, proved too difficult for most candidates.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- Better performing candidates set out calculations in a logical sequence.
- In calculations, candidates are advised to carry through intermediate values held on their calculators, thus avoiding approximating divergence.
- List answers often contain contradictions or errors and should be avoided.

General comments

There was a tendency to over approximate during the course of a calculation. Internal approximation usually leads to an increase in the divergence of a candidate's result from the actual answer. This is particularly significant in multistage calculations such as **Question 1(a)(i)**, where 0.003 was often used for 0.00332.

There was a difference in success between numerical and chemical questions; the table data calculations were answered better than the textual chemical questions.

The basis for this examination is experimental investigation, however, there is a need for basic chemical knowledge. This was displayed in **Question 1(b)**, where candidates had difficulty with redox; a significant number of candidates did not understand the reaction to be $2\text{Cu}^{2+} + 4\text{I}^- \rightarrow \text{I}_2 + 2\text{CuI}$ and stated incorrectly that no I_2 would be formed. Also, H^+ in **Question 1(b)(ii)** was commonly incorrectly considered to be reduced in the reaction.

Candidates should be encouraged to consider their responses in order to avoid non-specific responses. Answers such as '*the time was recorded wrongly*', '*the temperature of the solution was not 25 °C*' and '*the timer was started and stopped too early*', in **Question 2(e)** illustrate this.

The tendency to over-answer was present, perhaps in the hope of multiple answers providing something being correct; this approach is almost certain to fail. The danger to the candidate is that numerous answers often contradict each other. For example, in **Question 1(d)(i)**:

*'The time taken was longer
because the molecules are closer together
so the intermolecular forces are greater
thus the viscosity decreased.'*

This response shows how the final, incorrect, response contradicts and negates the previous two correct statements.

Comments on specific questions

Question 1

- (a) (i) Many candidates were able to successfully transfer their experience into a novel situation. Most candidates correctly calculated the moles of Y_2O_3 and applied that properly, along with stoichiometric ratio of 1:4:6 and M_r to $BaCO_3$ and CuO . A common error was to use an incorrect stoichiometric ratio, such as 1:2:3; others wrongly applied the 0.750 g to $YBa_2Cu_3O_7$.

A significant number of candidates used inappropriate rounding; this affected their calculated values for $BaCO_3$ and CuO . The moles of Y_2O_3 of 3.32×10^{-3} were often rounded to 3×10^{-3} , which produced about a 10 percent difference in the final answers. Other inappropriate rounding was the 0.0132 moles of $BaCO_3$ to 0.013 and the 0.0199 to 0.02 moles, which introduced further deviation. Often candidates wrote a rounded value in their calculation but used a retained calculator value in subsequent calculations; it is inappropriate to see intermediate values given to one significant figure with final values given to more significant figures.

Candidates should be advised never to approximate, round or truncate intermediate calculation values.

- (ii) This straightforward question was rarely answered successfully. Some, incorrectly, suggested dissolving the compound in water and filtering; others just weighing or reheating or putting the solid in a sealed container to prevent the solid from coming in contact with oxygen or carbon dioxide. A significant number of candidates did not realise that the purpose of heating/weighing to constant mass was to maximise yield in a reaction that produced a gas. Many candidates erroneously assumed that the procedure was to remove water, presumably because heating to constant mass is a procedure that is often applied to drying. These candidates answered the question out of context. Indeed, the provided reaction equation clearly shows that no water was produced.

It is appropriate to remind candidates to read the question properly and answer the question asked and not the one that they assumed they were asked.

- (b) (i) Candidates found this a difficult question with many showing confusion over redox. This question was often over-answered, usually with conflicting answers leading to no credit. A standard correct response was 'the Cu^{2+} would react with the I^- to make CuI ' on the basis that I_2 is added in step 3 following no removal of Cu^{2+} in step 2. Unfortunately, this was often followed with 'this means that no I^- would be available for Br_3^- in step 3' or 'when Cu^{2+} reacts with I^- no I_2 will be formed'. These additional incorrect responses negated any correct response.

In the first case, step 3 clearly states 'Excess I^- is added ...' so the reasoning is invalid. In the second case, the I^- that reacts with the Cu^{2+} is oxidised, as shown by the first item of data, to produce I_2 , so instead of no I_2 being produced, in fact more I_2 would be produced. Many candidates quoted the Cu^{2+}/CuI half equation but did not link it to the I_2/I^- half equation so missed the link between oxidation and reduction. Throughout this question, there was confusion over the roles of the reagents with Cu^{2+} and/or I^- being described as an oxidising agent or reducing agent.

Candidates should be advised to avoid over answering with multiple responses, which often contain incorrect statements and negates any correct response.

- (ii) This question was less well answered than (b)(i). A common incorrect response was that ' H^+ reacted with the I^- '. Very few candidates understood that the iodide ions would be oxidised in acid solution. Others suggested that removal of the hydrogen ion was essential to prevent a reaction with the sodium thiosulfate. Very few candidates referred to the final item of data, which clearly shows O_2 being reduced in the presence of H^+ . H^+ was often considered to be an oxidising agent rather than its role in the equation of producing water.

The responses in (b)(i) and (b)(ii) demonstrated a lack of familiarity with redox and redox potentials and not linking two redox half reactions together. Only a handful of candidates properly combined two half equations to give a feasible redox.

- (iii) The vast majority of candidates were successful with this calculation.

- (c) (i) Virtually all candidates answered this correctly.
- (ii) Many candidates were not entirely successful in answering this question. The basic answer starts with dissolving the solid in the beaker in distilled water, transferring the solution to a 250 cm³ volumetric flask, rinsing the beaker and putting the rinsings into the volumetric flask and finally making up to the mark. The most common omission was failing to mention rinsing the beaker and transferring these rinsings. Many did not make the solution in the beaker but placed the solid directly into the volumetric flask, whilst others thought the citrate was a solution. Often, some candidates transferred the solution in the beaker using pipettes, measuring cylinders or even burettes, all of which are inappropriate.
- (d) The objective to achieve concordancy across at least two values was understood by most candidates. Recognition of the lack of concordancy and the need to repeat titrations until concordancy was achieved gained full credit. Some candidates erroneously considered that the burette should be reset to 0.00 cm³. Suggestions of method improvements, such as adding dropwise as the end point was approached to make concordancy more likely, were credited. A few candidates thought, incorrectly, the iodine solution was in the burette.

Question 2

- (a) Removing acids with water and the subsequent drying with a volatile liquid such as propanone is a standard technique. The key requirement for this question was that firstly acid, then secondly, water was removed from the viscometer. Popular incorrect responses included dilution (rather than removal) and removal of (unspecified) impurities.
- (b) The calculation of the table data was generally correct. There were very few calculation or rounding errors. Observed errors in column 6 were stating 0.0220 for 0.0221 and 0.0239 for 0.0240. The majority of observed errors were not giving the values to three significant figures or quoting fractions in column 1. Some candidates gave the results in column 6 to two decimal places rather than three significant figures. Quoting values to two decimal places in column 6 resulted in only two values, 0.02 and 0.03, which then presented difficulties in plotting the graph.
- (c) The plotting of the data was virtually without fault. Furthermore, virtually all candidates presented a good line of best fit through the data.
- (d) (i) Most candidates understood that the time taken would be greater, but many did not give an adequate explanation. These candidates seemed to be more concerned with the kinetic energy/speed of the molecules rather than the viscosity of the solution. A significant number of candidates who correctly answered that time would be greater, then contradicted themselves by concluding that viscosity decreased.
- (ii) Many candidates suggested a water-bath but failed to suggest any form temperature regulation for the water-bath. Some candidates suggested a temperature-controlled room or an incubator; neither would be practical in this context.
- (e) Virtually all candidates correctly identified the anomalous result. Even though the question stated the concentration of the solution was correct, a few candidates stated that the concentration here was higher/lower. Candidate over-answering caused some problems here.
- (f) (i) The initial requirement was to extrapolate the line back to read the intercept at $c = 0$ which most, but not all, candidates managed.
- (ii) This question was generally answered correctly with candidates being able to manipulate log calculations successfully. A small number did not antilog their calculated value and some used log to base e in either or both log operations.
- (iii) The question required division of the previously calculated M_r by the M_r of phenylethene (104). A small number of candidates did not use the correct M_r of phenylethene. The majority of candidates stated a whole number but sometimes with a rounding error.
- (g) Most candidates realised that the value of 'a' would be higher for poly(ethanol) dissolved in water. However, the explanation was not always adequate or clearly stated. Many understood that hydrogen bonds would be made between the poly(ethanol) and water but did not state that these

bonds were stronger than the intermolecular bonds between the poly(phenylethene) and methylbenzene.