CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

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

Questions 1, **21**, **30**, **34** and **39** were found to be more challenging to candidates.

Comments on specific question

Question 1

The most commonly chosen incorrect answer was **C**. From the Data Booklet the element is gallium. When three electrons have been removed, the electronic configuration of the Ga^{3+} ion is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$. The third shell is full at this point. Therefore, the removal of the fourth electron, giving Ga^{4+}, is from a filled shell.

Question 21

The most commonly chosen incorrect answers were **B** and **C**. This suggests that many candidates did not appreciate the significance of the phrase ‘has a branched carbon skeleton’, and they included one or both of pentan-2-ol and pentan-3-ol. However, the only compound with molecular formula $C_5H_{12}O$, a branched carbon skeleton and a secondary alcohol group, is 3-methylbutan-2-ol.

Question 30

The most commonly chosen incorrect answer was **D**. From the infra-red spectrum, **K** clearly has a C=O group but no COOH group; it is therefore an aldehyde or a ketone. This rules out **D**. The conditions stated in the question would oxidise an aldehyde to a carboxylic acid. Therefore, **K** is a ketone and **J** must be a secondary alcohol. The answer cannot be **B** as this structure does not have a branched chain. Therefore, the answer is **C**.

Question 34

The most commonly chosen incorrect answer was **B**. Choice **B** would mean statements 1 and 2 are correct. However, statement 1 cannot be correct as there is no gas produced in this reaction. Statement 2 refers to the ‘disappearing cross’ experiment, so this statement is true. Statement 3 is also true as the reaction causes a decrease in the concentration of ions present. The answer is therefore **C**.

Question 39

The most commonly chosen incorrect answer was **C**. This was a challenging question involving careful thought.

- If compound 1 undergoes an addition reaction with steam, butane-1,3-diol is produced. If this is oxidised, 3-oxobutanoic acid is produced. Statement 1 is therefore true.
- If compound 2 undergoes a substitution reaction with OH^-, 3-hydroxybutanoic acid is produced. If this is oxidised, 3-oxobutanoic acid is produced. Statement 2 is therefore true.
- If compound 3 undergoes a substitution reaction with OH^-, 3-hydroxybutanal is produced. If this is oxidised, it gives 3-oxobutanoic acid. Statement 3 is therefore true.

All three statements are true, so therefore the answer is **A**.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

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

Questions 4, **29**, **35**, **36** and **38** were found to be more challenging to candidates.

Comments on specific questions

Question 4

The most commonly chosen incorrect answer was **A**. In each set of three substances the first and second substance is planar. Phosphine, PH_3, is not planar due to the lone pair on the phosphorus atom. Water is a planar molecule since any molecule with only three atoms must be planar, so the correct answer is **D**.

Question 29

The three incorrect responses were chosen with almost equal frequencies, suggesting that many candidates guessed their answer. Looking at the four compounds in sequence:

- **A** can be treated with hot concentrated acidified potassium manganate(VII), this gives propanoic acid as one product, so **A** is the correct answer.
- **B** can be hydrolysed, but the product is butanoic acid.
- **C** can be hydrolysed, but the product is 2-hydroxypropanoic acid.
- **D** can be oxidised, but the product is propanone.

Question 35

The three incorrect responses were chosen with almost equal frequencies, suggesting that many candidates guessed their answer. Statement 1 is correct, when Al_2Cl_6 is added to water the pH of the solution formed is typically between 2 and 4. Statement 2 is incorrect, one mole of Al_2Cl_6 requires six moles of NaOH to form aluminium hydroxide. Statement 3 is incorrect, Z contains $2x$ mole of aluminium.

Question 36

The most commonly chosen incorrect answer was **A**. Many candidates were unsure of statement 3. Calcium hydroxide is indeed used in agriculture to treat soils, but when it is added to soil it raises the pH; it does not lower the pH. Statement 3 is therefore untrue.

Question 38

The most commonly chosen incorrect answer was **B**. Many candidates were unsure of statement 2, which states, *'Only tertiary halogenoalkanes are hydrolysed in this way'.* The 'this way' refers to the S_N1 mechanism. However, a secondary halogenoalkane can be hydrolysed by a mixture of the S_N1 mechanism and the S_N2 mechanism, depending on structure. Statement 2 is therefore untrue.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

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Questions 1, **21**, **30**, **34** and **39** were found to be more challenging to candidates.

Comments on specific question

Question 1

The most commonly chosen incorrect answer was **C**. From the Data Booklet the element is gallium. When three electrons have been removed, the electronic configuration of the Ga^{3+} ion is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$. The third shell is full at this point. Therefore, the removal of the fourth electron, giving Ga^{4+}, is from a filled shell.

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- If compound 3 undergoes a substitution reaction with OH^-, 3-hydroxybutanal is produced. If this is oxidised, it gives 3-oxobutanoic acid. Statement 3 is therefore true.

All three statements are true, so therefore the answer is **A**.

CHEMISTRY

Paper 9701/21
AS Structured Questions

Key messages

- Candidates should avoid the early rounding of intermediate answers during calculations.
- Candidates are reminded that observations for a chemical reaction should focus on the physical changes that take place.
- The use of the Data Booklet should be encouraged for questions involving infra-red spectra.
- When a question asks for a name of a reagent(s) then the formula of reagent(s) is not acceptable.

General comments

Many candidates are advised to improve their knowledge of the chemistry associated with questions on environmental topics.

Candidates should be encouraged to carefully read questions and check their responses to make sure they have fully answered what is required.

Some candidates should be encouraged to balance equations with more care.

The use of ‘molecular formula’ appeared to cause problems as it was often confused with structural formula.

Comments on specific questions

Question 1

(a) (i) The full electronic configuration of the Fe^{2+} ion, $1s^22s^2p^63s^23p^63d^6$, was not given very often. Many answers were correct up to $3p^6$, but were then followed by either $4s^23d^6$ or $4s^13d^5$.

(ii) Generally, the correct oxidation number of –1 for sulfur, in S^{2-}, was stated by the majority of candidates.

(b) Metallic bonding diagrams were often not labelled. Many answers described a lattice of positive ions surrounded by a ‘sea of delocalised electrons’ but did not mention the electrostatic attractions between these ions and the delocalised electrons, to describe the metallic bonding.

(c) (i) The environmental consequence of the release of sulfur dioxide into the atmosphere to form acid rain was generally well answered. The explanation for the consequences of forming acid rain, in the atmosphere, were often correctly stated. Many answers focused exclusively on the formation of sulfuric acid.

(ii) Completing the equation for the roasting of iron pyrite in oxygen was generally well answered where the majority of answers contained equations with O_2 and SO_2 as reactant and product respectively. The correct stoichiometry of 11:8 was not always given. Many candidates either ignored or did not consider the **4**FeS_2 and gave answers for equations with **1**FeS_2.

(iii) The majority of candidates correctly calculated the number of moles of Fe_2O_3 but then did not use the stoichiometry of the equation to determine the number of moles of FeS_2, before converting to a mass in grams.

(iv) The percentage by mass of gold in the impure iron pyrite is calculated as 0.37 ÷ (mass of FeS_2 + 0.37). Many candidates did not include the original given mass of 0.37 g of gold in their calculation.

Question 2

(a) (i) Many answers correctly stated that nitrogen, $N_{2,}$ is non-polar and contains a triple bond, which requires a large amount of energy to break during reactions.

(ii) Correct 'dot-and-cross' diagrams were common showing three pairs of shared electrons between the two N atoms. Some responses attempted to place all seven electrons of nitrogen in the outer shell.

(b) (i) Several answers mentioned that high energy was required for the reaction of N_2 and O_2, but did not link it to the lightning strike.

(ii) Many answers mistakenly gave equations of NO and O_2 forming NO_3 and/or a second equation, between NO_2 and H_2O to form H_2 or O_2 as products. Several responses gave an incorrectly balanced equation. There were a few good answers of equations showing that NO is first converted to NO_2 and then to nitric acid, HNO_3.

(c) Many candidates appreciated how fertilisers enter natural water supplies and that there is a reduction in the concentration of oxygen in the affected water supplies.

Very few candidates clearly understood what caused the drop of oxygen concentration in the water. The bacteria/micro-organisms break down the decaying/dead algae and use up the dissolved oxygen in the water source. Many responses stated that the algae used up the dissolved oxygen.

(d) (i) The majority of answers correctly stated that calcium hydroxide was added to soils to reduce the acidity for optimum crop yields.

(ii) Many answers correctly identified ammonia as the gas released when calcium hydroxide reacts with ammonium salts.

It was clear that some candidates did not understand that the ammonium ion is acidic and donates a proton to the hydroxide ion in the calcium hydroxide in a simple neutralisation reaction.

(iii) This question required observations from a chemical reaction and proved challenging. Many responses stated that 'a gas was given off' and few answers gave bubbling/effervescence for an observation.

That the (white) solid, $CaCO_3$, dissolves or disappears was less well known.

(iv) A balanced equation for the 'thermal decomposition' of calcium nitrate proved challenging for many. Frequently the stoichiometry for one of the products, oxygen, was incorrect and a few responses confused 'thermal decomposition' with 'combustion' and included oxygen as a reactant.

Question 3

(a) (i) The majority of candidates found this question challenging. Very few responses mentioned that the pressure of a gas/vapour, above a liquid, exists in a state of equilibrium. Very few answers understood that the 'high', in 'high pressure', was due to a large number of gaseous particles colliding with the walls of a vessel.

(ii) Many correct calculations were seen. Common errors included use of the expression 'reactants – products' to give a value of +17.

(iii) Several definitions of the term *heterogeneous* incorrectly stated that both the reactants and products were in a different phase. Many answers correctly stated that the catalyst 'lowered the activation energy' but did not mention that this resulted in an 'increase in the rate of reaction'.

(b) (i) Many candidates did not understand that the term *enhanced greenhouse effect* is due to 'human activity' which creates the additional greenhouse gases. Several responses confused the 'greenhouse effect' with 'acid rain' and/or 'ozone depletion'.

(ii) The majority of answers described the effect on the 'ozone layer' by the formation of free radicals but did not mention that $CHC\ell F_2$, as with other greenhouse gases, traps heat/stops heat from radiating into space, causing an increase in global warming.

(iii) The other principal environmental problem associated with the use of $CHC\ell F_2$ of 'ozone depletion' was not understood by the majority of candidates.

(c) (i) Most candidates correctly described the type of polymerisation for the production of an 'ethene' derivative.

(ii) Many candidates were awarded credit for correctly drawing the repeat unit for PTFE.

(iii) The unreactive nature of PTFE, when used as a coating for cooking pans, was generally understood by most candidates.

(iv) The difficulty in disposing of PTFE was linked to its non-biodegradable characteristics by many candidates. Many answers offered vague statements for its disposal and were not awarded full credit.

4(a) Many answers for the observations of the reactions of the alcohol and carboxylic acid functional groups, in glycolic acid, included incorrect statements that 'a gas was observed' or an 'orange precipitate' formed when 2,4-DNPH was added to an acid functional group.

(b) (i) Generally the structure of **X** was answered well by most candidates.

(ii) Naming the reagent for the hydrolysis of a nitrile proved challenging to many candidates. The majority of responses gave a formula, instead of the name, as specified by the question.

(iii) The majority of candidates did not recognise that the reaction of the alkyl group of ethanoic acid with bromine is a free-radical substitution.

(iv) Most candidates who were awarded credit for **(iii)**, correctly stated UV light/sunlight as the essential condition for the free-radical reaction.

(v) Many answers for the mechanism of ^{-}OH and bromoethanoic acid were inaccurate by showing lone pairs on the H atom or suspended in space and not associated with any particular atom.

The curly arrow from the C–Br polar bond often started from the C atom and not from the middle of the C–Br bond.

(c) (i) It was generally well recognised that $NaBH_4$ acts as a reducing agent.

(ii) Many answers gave structural formulae in a question that specifically asked for 'molecular formulae'.

(d) (i) The infra-red spectrum question was challenging for many candidates. Many answers focused on C–H and/or C=O absorptions, which are present in both glycolic acid and derivative **Y**.

Absorptions for an O–H group in glycolic acid were often quoted as 2500–3000 cm^{-1} and 3200–3650 cm^{-1}. Very few answers linked these absorptions to the O–H group in either the alcohol or carboxylic acid groups, both of which are present in glycolic acid.

(ii) Several candidates were able to identify the structure for **Y** as a cyclic ester. Many answers contained structures with a molecular formula of $C_4H_4O_4$ but which bore no resemblance to structures containing an ester functional group.

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key messages

- Those candidates who were successful on this paper had a very good knowledge and understanding of the topics tested and were able to apply this knowledge to different situations successfully.
- Careful reading of all the information given in a question is essential.
- Candidates should be encouraged to show their working, whether in questions involving quantitative answers or when deducing correct structures in organic chemistry. Any working which the candidate does not wish to be considered should be crossed out with a single line.

General comments

Many excellent responses were seen. Some answers, particularly involving explanations of key areas of the syllabus, were confused as a result of the use of inappropriate key vocabulary. Elements, atoms, compounds, molecules, shells, sub-levels and orbitals were often seen in incorrect contexts.

Candidates who showed clear logical working in items which involved application of knowledge or in calculations, tended to produce more accurate responses. In numerical answers which were not fully correct it was possible to award credit for correct method or part method when working was shown.

Candidates should be familiar with the use of the symbols [O] and [H] to represent oxidising agents and reducing agents, in equations, in organic chemistry.

Comments on specific questions

Question 1

(a) Many answers correctly described the relative mass and charge of a neutron. Some answers gave the value for the mass of the neutron in kg, based on the information given in the Data Booklet. The description of the location of an electron, within an atom, was generally given correctly in terms of shells or orbitals or sub-levels. Weaker answers gave more general comments like ‘outside the nucleus’ or ‘in orbits’ Many candidates used the mass number minus the number of electrons to calculate correctly the number of neutrons.

(b) Identification of metallic bonding in gold metal foil was seen regularly. A relatively small number of answers described the bonding as ionic.

(c) (i) Many responses correctly described the meaning of the term isotope in terms of the number of protons and the number of neutrons. Many answers did not identify the species behaving as isotopes as ‘atoms of the same element’. Incorrect use of the term ‘element’ for ‘atom’ occurred. Occasional confusion with the term isomer was also seen.

(ii) Answers which explained why the chemical properties of the isotopes of gold are identical in terms of the identical electron configuration of these atoms were seen. Some responses focused only on the true statement that different isotopes of gold contain the same number of protons but did not explain why the chemical properties are identical.

(d) (i) Correct calculation of the percentage abundance of gold in tumbaga, using the information from the mass spectrum, was seen.

(ii) The majority of candidates showed an understanding of how the relative atomic mass can be calculated. Good answers successfully interpreted all the information given and used the relative abundance of ^{63}Cu and ^{65}Cu in the calculation. The most common mistake was to ignore the presence of gold in the sample and use the percentage abundances of the two copper isotopes given in the mass spectrum.

Question 2

(a) The question was answered well by candidates with a good knowledge of the significance of periodicity in terms of physical and chemical properties of the elements in the third period. Some confusion was seen when describing the bonding in magnesium and aluminium as ionic. The incorrect formula of sodium oxide or the chloride of silicon was also seen.

(b) (i) Many candidates used their knowledge of the number of valence shell electrons in sulfur and chlorine to draw correct 'dot-and-cross' diagrams to show the bonding involved in SCl_2.

(ii) Correct use of the information given to complete the reaction profile, showing an exothermic reaction, was seen in the majority of answers. Good responses showed correct annotation of the diagram. Weaker answers demonstrated confusion when identifying the activation energy and/or enthalpy change for the reaction.

(c) (i) The majority of answers correctly sketched the trend in melting point increasing from sodium to silicon and then decreasing. Some answers did not identify silicon as the element with the highest melting point.

(ii) Explanation of the trend in melting points across Period 3 proved to be challenging. There were a small number of excellent answers, which linked the changes to the differences in bonding and structure of the elements. The significance of increased strength of metallic bonding from sodium to aluminium was rarely seen. Confusion was seen relating to the breaking of covalent bonds to melt sulfur and/or phosphorus or descriptions of silicon as simple molecular. Some answers described the factors which affect the ionisation energies of these elements or the change in atomic size across the period.

(d) Equations to describe the reaction of P_4O_{10} and water proved to be challenging. Some answers correctly described an equation, which showed the correct product but did not balance the equation correctly. Weaker answers did not state the correct formula of phosphoric acid or showed production of hydrogen gas.

(e) The formation of acid rain and an environmental consequence were well known. Many candidates correctly described the process involved to make acid rain from sulfur dioxide emissions, although this was not asked for.

(f) Correct identification of the two pairs of elements which did not show an increase in first ionisation energy and the idea that the ionisation energy process involved loss of electrons were seen in many answers. Inappropriate use of the terms sub-level and orbital and answers which did not specify the energy level from which the electron was removed created ambiguity in weaker responses.

Question 3

(a) Many excellent, clear and logical responses which showed how to calculate the enthalpy change for the reaction by constructing an appropriate Hess' Cycle were seen. Common mistakes ignored the stoichiometry given in the equation or calculated the enthalpy change for the reverse reaction.

(b) (i) Three properties of ideal gases were clearly described in a small number of answers. Many answers listed general behaviour of all gases rather than those which related specifically to ideal gases, for example the constant movement of gas particles. Weaker answers made no reference to the terms 'molecules' or 'particles' but referred only to 'the gas'.

(ii) A significant number of responses correctly described the closer proximity of the molecules under high pressure. The best answers appreciated that in order to fit the results given there must be an increase in forces of repulsion between the molecules or that the volume of the molecules must become significant. Many answers described the formation of intermolecular forces in the explanation despite this not fitting with the data shown in the graph at 300 atmospheres.

(c) (i) Candidates were expected to use the formulae of all the reactants and products described in the details of the question to construct a balanced chemical equation. It was common to see equations which showed the correct formulae of reactants and products without an attempt to balance the equation. Other incorrect answers changed the formula of carbonyl dichloride so that balancing the oxygen gas molecules was not required.

(ii) A significant number of answers identified the peak on the infra-red spectrum of $COCl_2$, which would not be seen on an infra-red spectrum of $CHCl_3$ and gave an appropriate explanation in terms of the absence of the C=O bond in trichloromethane.

(iii) Many answers correctly identified the presence of a peak at 2850 – 2950 cm^{-1} in trichloromethane, which would not be present in carbonyl dichloride. There was confusion by some candidates who identified the wavenumber range, which corresponded to the C-H bond in =C-H rather than in CH_2-H.

Question 4

(a) (i) Candidates were required to draw the displayed formula of **P**, which was formed when ethanal reacted with HCN and NaCN. Many answers were seen which identified the product. Only a relatively small number of answers showed **P** as a displayed formula, showing the relative placing of atoms and the number of bonds between all the atoms within the molecule.

(ii) Conversion of the alcohol functional group to an alkene was commonly described as an elimination rather than a dehydration reaction. Common incorrect answers included hydration, reduction, substitution and condensation reactions.

(iii) Candidates were not confident using the symbol [O] to represent the oxidising agent when writing the balanced equation showing the conversion of **Q** to **P**. Very few answers included the formation of H_2O as a product.

(iv) Many answers correctly stated the reagent used to oxidise the secondary alcohol group, **Q**, to form the ketone. Incorrect formulae and the omission of the acid conditions was seen.

(b) (i) The majority of answers described the meaning of the term stereoisomer, which could be applied to both geometrical (cis-trans) and optical isomers. Answers which attempted to describe optical isomers rather than give a general term for stereoisomer often referred to mirror images with no reference to them being non-super(im)posable.

(ii) Representation of the two optical isomers of **Q**, which showed their three-dimensional structure, was generally well done. Ambiguity representing the different types of bond to show the tetrahedral structure was seen. Some answers showed the correct bond shapes but with bond angles of 90° rather than a tetrahedral structure.

(c) Many candidates were able to apply their knowledge of addition polymerisation to deduce correctly one repeat unit of the intermediate polymer. A relatively small number of answers appreciated that the addition of aqueous sodium hydroxide would produce a repeat unit which contained the sodium salt of the carboxylic acid functional group.

(d) (i) This question proved to be challenging. Good answers successfully explained the increased stability of intermediate **I** in terms of the increased inductive effect, caused by more alkyl groups on the intermediate cation, which resulted in reduction of the positive charge on the central carbon atom. Some answers correctly linked the presence of more alkyl groups to the stability of the intermediate. Many candidates struggled to explain the inductive effects of the alkyl groups on the stability of the intermediate cations. Confusion with appropriate use of the term alkyl, methyl and ethyl groups was noted in some answers.

(d)(ii) Many good diagrams were produced which showed the key details of the mechanism used to convert **Z** to **T**.
There was occasional confusion regarding the direction of the arrows to represent the movement of pairs of electrons from the carbon double bond or the arrow head pointing to the hydrogen bromide bond rather than the $\delta+$ hydrogen atom. Often the bromide species produced during the mechanism was not shown with a negative charge associated with it.

(d)(iii) The majority of candidates correctly named the mechanism for the conversion of **T** to 2-aminopropane.

(e) (i) The key to answering this question was a knowledge of the effect of $LiAlH_4$ on different functional groups. Very few answers showed the ketone group reduced to a secondary alcohol and the carboxylic acid reduced to a primary alcohol. Incorrect structures included reducing only one of the functional groups or reducing the carboxylic acid to an aldehyde. A common error showed the structural formula of the organic product as $CH_3CH(OH)CH(OH)_2$.

(ii) Many answers correctly described the electronic configuration of the sodium ion. Occasionally, candidates described the electronic configuration of the sodium atom.

(iii) It was common for responses to suggest an explanation of increasing ionic radius down Group 1 in terms of increased number of shells or the idea that the outer shell is further away from the nucleus. Some answers described the increased shielding effect down the group.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key messages

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- When a question asks for a name of a reagent(s) then the formula of reagent(s) is not acceptable.

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Comments on specific questions

Question 1

(a) (i) The full electronic configuration of the Fe^{2+} ion, $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$, was not given very often. Many answers were correct up to $3p^6$, but were then followed by either $4s^2 3d^6$ or $4s^1 3d^5$.

(ii) Generally, the correct oxidation number of –1 for sulfur, in S^{2-}, was stated by the majority of candidates.

(b) Metallic bonding diagrams were often not labelled. Many answers described a lattice of positive ions surrounded by a 'sea of delocalised electrons' but did not mention the electrostatic attractions between these ions and the delocalised electrons, to describe the metallic bonding.

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(iii) The majority of candidates correctly calculated the number of moles of Fe_2O_3 but then did not use the stoichiometry of the equation to determine the number of moles of FeS_2, before converting to a mass in grams.

(iv) The percentage by mass of gold in the impure iron pyrite is calculated as 0.37 ÷ (mass of FeS_2 + 0.37). Many candidates did not include the original given mass of 0.37 g of gold in their calculation.

Question 2

(a) (i) Many answers correctly stated that nitrogen, N_2, is non-polar and contains a triple bond, which requires a large amount of energy to break during reactions.

(ii) Correct 'dot-and-cross' diagrams were common showing three pairs of shared electrons between the two N atoms. Some responses attempted to place all seven electrons of nitrogen in the outer shell.

(b) (i) Several answers mentioned that high energy was required for the reaction of N_2 and O_2, but did not link it to the lightning strike.

(ii) Many answers mistakenly gave equations of NO and O_2 forming NO_3 and/or a second equation, between NO_2 and H_2O to form H_2 or O_2 as products. Several responses gave an incorrectly balanced equation. There were a few good answers of equations showing that NO is first converted to NO_2 and then to nitric acid, HNO_3.

(c) Many candidates appreciated how fertilisers enter natural water supplies and that there is a reduction in the concentration of oxygen in the affected water supplies.

Very few candidates clearly understood what caused the drop of oxygen concentration in the water. The bacteria/micro-organisms break down the decaying/dead algae and use up the dissolved oxygen in the water source. Many responses stated that the algae used up the dissolved oxygen.

(d) (i) The majority of answers correctly stated that calcium hydroxide was added to soils to reduce the acidity for optimum crop yields.

(ii) Many answers correctly identified ammonia as the gas released when calcium hydroxide reacts with ammonium salts.

It was clear that some candidates did not understand that the ammonium ion is acidic and donates a proton to the hydroxide ion in the calcium hydroxide in a simple neutralisation reaction.

(iii) This question required observations from a chemical reaction and proved challenging. Many responses stated that 'a gas was given off' and few answers gave bubbling/effervescence for an observation.

That the (white) solid, $CaCO_3$, dissolves or disappears was less well known.

(iv) A balanced equation for the 'thermal decomposition' of calcium nitrate proved challenging for many. Frequently the stoichiometry for one of the products, oxygen, was incorrect and a few responses confused 'thermal decomposition' with 'combustion' and included oxygen as a reactant.

Question 3

(a) (i) The majority of candidates found this question challenging. Very few responses mentioned that the pressure of a gas/vapour, above a liquid, exists in a state of equilibrium. Very few answers understood that the 'high', in 'high pressure', was due to a large number of gaseous particles colliding with the walls of a vessel.

(ii) Many correct calculations were seen. Common errors included use of the expression 'reactants – products' to give a value of +17.

(iii) Several definitions of the term *heterogeneous* incorrectly stated that both the reactants and products were in a different phase. Many answers correctly stated that the catalyst ‘lowered the activation energy’ but did not mention that this resulted in an ‘increase in the rate of reaction’.

(b) (i) Many candidates did not understand that the term *enhanced greenhouse effect* is due to ‘human activity’ which creates the additional greenhouse gases. Several responses confused the ‘greenhouse effect’ with ‘acid rain’ and/or ‘ozone depletion’.

(ii) The majority of answers described the effect on the ‘ozone layer’ by the formation of free radicals but did not mention that $CHC\mathit{l}F_2$, as with other greenhouse gases, traps heat/stops heat from radiating into space, causing an increase in global warming.

(iii) The other principal environmental problem associated with the use of $CHC\mathit{l}F_2$ of ‘ozone depletion’ was not understood by the majority of candidates.

(c) (i) Most candidates correctly described the type of polymerisation for the production of an ‘ethene’ derivative.

(ii) Many candidates were awarded credit for correctly drawing the repeat unit for PTFE.

(iii) The unreactive nature of PTFE, when used as a coating for cooking pans, was generally understood by most candidates.

(iv) The difficulty in disposing of PTFE was linked to its non-biodegradable characteristics by many candidates. Many answers offered vague statements for its disposal and were not awarded full credit.

4(a) Many answers for the observations of the reactions of the alcohol and carboxylic acid functional groups, in glycolic acid, included incorrect statements that ‘a gas was observed’ or an ‘orange precipitate’ formed when 2,4-DNPH was added to an acid functional group.

(b) (i) Generally the structure of **X** was answered well by most candidates.

(ii) Naming the reagent for the hydrolysis of a nitrile proved challenging to many candidates. The majority of responses gave a formula, instead of the name, as specified by the question.

(iii) The majority of candidates did not recognise that the reaction of the alkyl group of ethanoic acid with bromine is a free-radical substitution.

(iv) Most candidates who were awarded credit for **(iii)**, correctly stated UV light/sunlight as the essential condition for the free-radical reaction.

(v) Many answers for the mechanism of ^-OH and bromoethanoic acid were inaccurate by showing lone pairs on the H atom or suspended in space and not associated with any particular atom.

The curly arrow from the C–Br polar bond often started from the C atom and not from the middle of the C–Br bond.

(c) (i) It was generally well recognised that $NaBH_4$ acts as a reducing agent.

(ii) Many answers gave structural formulae in a question that specifically asked for ‘molecular formulae’.

(d) (i) The infra-red spectrum question was challenging for many candidates. Many answers focused on C–H and/or C=O absorptions, which are present in both glycolic acid and derivative **Y**.

Absorptions for an O–H group in glycolic acid were often quoted as 2500–3000 cm^{-1} and 3200–3650 cm^{-1}. Very few answers linked these absorptions to the O–H group in either the alcohol or carboxylic acid groups, both of which are present in glycolic acid.

(ii) Several candidates were able to identify the structure for **Y** as a cyclic ester. Many answers contained structures with a molecular formula of $C_4H_4O_4$ but which bore no resemblance to structures containing an ester functional group.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

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 ensure they have carried out the instructions given. Highlighting key words may be of assistance to some.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with regard to colour and state.
- Candidates should be instructed to complete the boxes relating to session and laboratory on the front of the paper, unless a single laboratory was used for the whole entry from the centre.
- In qualitative analysis exercises candidates should be careful to use the correct terms for e.g. precipitate and solution and also to describe colours precisely. The use of the Qualitative Analysis Notes is advised.

General comments

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. This is achieved by centres returning the following documentation within each script packet for each session and for each laboratory within a session:
- 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.

This paper proved accessible to all candidates and it generated a wide range of marks. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Candidates completed the practical work to a generally high standard. Fewer candidates were able to gain full credit on the graphical section of the question. They should be encouraged to keep the scales simple and to read instructions carefully before drawing lines of best fit. The calculation was well executed in parts. Candidates need to be aware of what each term represents in the equation energy released = $mc\Delta T$.

(a) Almost all candidates recorded the balance readings in the spaces allocated. A high proportion of candidates in some centres did not give thermometer readings to the expected .0 or .5 °C and a significant number did not record the initial temperature of **FA 1** i.e. temperature at time = 0. Although a variety of temperature rises were recorded many candidates' temperature changes were sufficiently close to the supervisor's for credit for accuracy to be awarded.

(b) (i) Only a minority of candidates gained full credit here. The common errors seen included ignoring the instruction to extend the *y*-axis by at least 2 °C, writing the label on the *x*-axis as time / s when minutes were recorded, imprecise plotting of points and either ignoring the instruction to draw the second line of best fit for the **cooling** of the mixture or having points unbalanced. If a line is to be considered a line of best fit, it is expected that there will be an equal number of points on either side of the line, ignoring any anomalous points. Most candidates selected a sensible scale making their plotting more accurate.

(ii) Many candidates gave a correct temperature rise. Some gave the maximum temperature from the graph rather than ΔT. Some candidates drew additional lines on their graphs contrary to instructions. These were usually from the temperature at time = 2 minutes to the maximum temperature.

(c) Answers were generally expected to be given to two to four significant figures.

(i) A number of candidates clearly knew that they needed to use energy released = $mc\Delta T$ but used an incorrect value for *m* (generally the mass of solid).

(ii)(iii) Many candidates recognised that it was necessary to divide by 27 000 and then multiply by 106.

(d) A large number of candidates correctly stated that they had assumed that the impurity did not react with hydrochloric acid. A significant minority merely commented on the relative amounts of sodium carbonate and impurity.

(e) Many candidates correctly recorded the relevant data and obtained experimental results that demonstrated that they had completed the practical exercise accurately.

(f) Some candidates structured their calculations well to receive full credit.

(g) A number of candidates correctly ticked the first box. Better performing candidates explained their choice in terms of the significance of using a cooling curve.

(h) A significant minority of candidates realised that fewer moles of carbonate were used. Better performing candidates went on to explain the effect of this on the value of ΔH. It was insufficient merely to say that the value was smaller or larger, since this did not make clear the direction of change for a negative value.

(i) Many candidates correctly calculated the volume of hydrochloric acid but a number omitted or incorrectly used the mole ratio involved.

Question 2

(a) (i) The majority of candidates used silver nitrate to test for the presence of a halide. Very few dissolved **FA 4** before adding the aqueous reagent. Most did obtain a white precipitate and correctly concluded that the anion present was chloride.

(ii) A significant number of correct equations were seen but a number omitted or gave incorrect state symbols.

(b) It was evident that many candidates carried out the practical correctly; however credit was not always awarded as not all observations were recorded.

(i) It was necessary to note both the effervescence and the formation of a blue/green solution in the first test and then the blue precipitate and its dissolution in excess ammonia to give a dark blue solution.

(ii) Candidates generally were more successful in this part, with only the test with sodium hydroxide and aluminium really producing any significant difficulties. In this test, the ammonia is only produced after the aluminium has been added.

(iii) Where correct observations were recorded, most candidates were able to use this information to identify the cations.

(iv)(v) Better performing candidates realised the significance of the difference between anions that **were** present in **FA 5** and anions that **could** be present.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

- Centres should ensure the chemicals supplied to candidates are fit for purpose and preferably freshly purchased.
- Candidates should record readings to the precision of the apparatus used. This is normally to half a division of the calibrated scale.
- Candidates should ensure they have carried out the instructions given. Highlighting key words may be of assistance to some.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with regard to colour and state.
- Candidates should be instructed to complete the boxes relating to session and laboratory on the front of the paper, unless a single laboratory was used for the whole entry from the centre.

General comments

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. This is achieved by centres returning the following documentation within each script packet for each session and for each laboratory within a session:

- 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.

This paper proved accessible to all candidates and it generated a wide range of marks. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Candidates were able to complete the practical work to a generally high standard. Fewer candidates performed well on the graphical section of the question. Candidates should be encouraged to keep the scales simple and to read instructions carefully before drawing lines of best fit. The calculation was well executed in parts. Candidates need to be aware of what each term represents in $q = mc\Delta T$ and in $\Delta H = -q/n$, such as n is the moles of limiting reagent. The section on errors and improvements was less well answered.

(a) Almost all candidates recorded the balance readings and mass of magnesium in the space allocated. A high proportion of candidates did not give thermometer readings to the expected .0 or .5 °C. A very wide range of temperature rises were seen. It is likely that some centres were using magnesium powder that had been largely oxidised as ΔT was less than 3.0 °C or did not reach a maximum in the eight minutes. Most centres reported ΔT between 50.0 and 65.0 °C. However, in many centres the candidates' ΔT values were sufficiently concordant for credit for accuracy to be awarded.

(b)(i) Only a minority of candidates were awarded full credit for the plotting of the graph. The most common errors were ignoring the instruction to extend the y-axis by at least 10 °C or writing the label on the x-axis as time / s when minutes were recorded, imprecise plotting of points and either ignoring the instruction to draw the second line of best fit for the **cooling** of the mixture or having points unbalanced. For a line of best fit, the expectation is that there will be an equal number of points either side of the line. Many candidates selected a sensible scale making their plotting more accurate.

(ii) A greater proportion of candidates determined ΔT correctly. Some gave the maximum temperature from the graph rather than ΔT. Some candidates drew additional lines on their graphs contrary to instructions. These were usually from the temperature at time = 2 minutes to the maximum temperature.

(c)(i)(ii)(iii)
Candidates were instructed to show appropriate significant figures in all final answers so an answer to **(i)** showing two significant figures or to **(iii)** showing five significant figures could not be credited. Many candidates calculated the concentration of **FA 1** and the moles of $CuSO_4$ correctly in **(i)** and **(ii)**. Some candidates ignored the statement regarding heat energy change and used the mass of magnesium from **(a)** rather than the volume of solution in **(iii)**. A small number of candidates mistakenly added 273 to their ΔT value from **(b)**.

(iv) Almost all candidates recognised that the enthalpy change was negative.

(v) The most common error was omitting the comparison of moles of magnesium with moles of $CuSO_4$. Almost all candidates correctly used 24.3 as the A_r of magnesium.

(d)(i) The majority of candidates noted that the magnesium turnings would take longer to react; very few commented successfully on how this would affect the accuracy of the experiment so could not be awarded credit. Answers in terms of heat loss were not relevant as a graphical method was used to compensate for this.

(ii) The most common correct answer was the use of a lid to prevent heat energy loss. Some excellent answers in terms of percentage error of apparatus were also seen.

Question 2

Many candidates gained good results in their practical work but the responses in the rest of the question varied considerably.

(a) The majority of candidates recorded their results successfully and performed better here than compared with **Question 1(a)**. The most common error was to omit the value of ΔT. A large majority of candidates reported an increase in temperature which gained credit for accuracy.

(b)(i) Most candidates gained credit for the negative sign. Similar errors were seen in the enthalpy change calculation in this part compared to those in **Question 1**.

(ii) Many candidates did not appreciate that a change in temperature required two thermometer readings, so the error was often not doubled.

(c) This question proved challenging for most candidates. A majority ticked the correct box (temperature rise would be approximately the same); most of those explained their answer in terms of doubling the mass of zinc, **FA 3**, as well as the volume or moles of **FA 1**. The doubling of the mass of zinc was to ensure it remained in excess so it did not become relevant. Only a small minority gave answers linking the doubling of heat energy evolved with the doubling of volume of solution to heat.

(d) A large minority of candidates omitted this part. Candidates should be reminded to label the arrows on any Hess cycle they construct with the relevant value from their calculations or from the default values given in the question. More candidates gained credit for the calculation than for the cycle.

Question 3

This proved to be challenging for many, though some good responses were seen. A common error was to omit the initial colour of solutions being tested.

(a) Many candidates recorded the expected colours in the reaction of **FA 4** with aqueous potassium iodide followed by aqueous sodium thiosulfate. A number of these reported a precipitate where there should be none or an incorrect colour of the sulfur precipitate slowly formed with the thiosulfate. Very few candidates reported the initial yellow colour of **FA 4** and many only gave the final colour. Candidates should be aware that adding a solid to a solution is not forming a precipitate. A higher proportion of candidates reported effervescence but many did not identify it as hydrogen.

(b)(i) Most candidates gave the correct tests for chloride and sulfate ions; fewer gave the correct test for nitrate. Some did not give the complete formula for the reagent and more did not specify the acid for which they were testing.

(ii) Most candidates gained full credit, with the majority testing for either sulfate or chloride.

(c) Few candidates reported more than two of the expected colours on adding the acidified potassium manganate(VII). Many candidates correctly reported a blue colour on adding **FA 6** to **FA 4**.

(d)(i) Candidates should be reminded that the term ‘redox’ should be used where a species in a reaction is oxidised or reduced as one cannot occur without the other. Some candidates described the type of reaction as displacement or neutralisation or exothermic, so did not link their answer to the colour changes they observed in **(c)**.

(ii) The majority of candidates successfully calculated the oxidation state of **M**.

CHEMISTRY

Paper 9701/34
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 ensure they have carried out the instructions given. Highlighting key words may be of assistance to some.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with regard to colour and state.
- Candidates should be instructed to complete the boxes relating to session and laboratory on the front of the paper, unless a single laboratory was used for the whole entry from the centre.

General comments

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. This is achieved by centres returning the following documentation within each script packet for each session and for each laboratory within a session:
- 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.

This paper proved accessible to all candidates and it generated a wide range of marks. The most challenging section involved an appreciation of errors and ways of improving the methods. Almost all candidates completed the paper indicating that there were few time constraints.

Comments on specific questions

Question 1

Candidates were able to complete the practical work to a generally high standard. The calculation was well executed in parts. Inclusion of state symbols in the equation caused problems for many.

(a) A majority of candidates recorded the balance readings and mass of sodium hydrogencarbonate in the space provided. A number wrote their data next to the instructions and often omitted the unit. A large minority of candidates did not record their burette readings for the rough titration. Most candidates produced tables of accurate readings and titres with correct headings and units. It was noticeable that in some centres neither the candidates nor the supervisor recorded their burette readings to 0.05 cm^3 as expected at this level. A majority of candidates achieved concordant titres and there were many gaining credit for accuracy.

(b) A large majority gained credit here. Those who were unsuccessful tended to select titres that were not concordant or did not display the answer correct to two decimal places.

(c)(i) Not all candidates gave all their final answers to three or four significant figures.

(ii) Almost all candidates started the calculation well by correctly calculating the number of moles of hydrochloric acid.

(iii) Fewer candidates were able to complete the equation successfully. Common errors were $HCl(l)$, $NaCl(s)$ and $H_2O(aq)$.

(iv) Candidates found this question challenging. Many candidates appeared to complicate their answer when only a factor of 10 and the answer to **(iii)** were required.

(v) Candidates found this challenging. Many of those who were unsuccessful in **(iv)** then tried to remedy this by inappropriate calculations. However, there were some very good answers with clear working shown.

Question 2

Many candidates gained good results in their practical work but the responses in the rest of the question varied considerably.

(a) Most candidates recorded their four weighings successfully but the headings were not always appropriate. **FB 1** was sodium hydrogencarbonate plus impurity so after heating, the solid was no longer **FB 1** but sodium carbonate plus impurity or more simply ‘residue’ or ‘contents’. A large minority confused mass of residue with mass loss in their calculations. Almost all candidates were able to gain some credit for accuracy.

(b)(i) There were many correct answers and a majority of these candidates successfully completed all of **(b)**.

(ii) Some candidates omitted the use of the mole ratio.

(iii) Those who confused residue with mass lost sometimes inverted the mass from **(ii)** and the ‘mass of residue’ to gain an answer of more than 100%.

(c)(i) This question proved challenging for most candidates. Many referred to heating to constant mass but then suggested that water was lost instead of both water and carbon dioxide.

(ii) It was not enough to state that the impurity did not react; reference to heating was needed as this was the method encountered. Candidates who stated that the impurity would evaporate did not understand the experiment they had carried out.

(iii) Few candidates answered this correctly, as they appeared unaware that use of a lid would not prevent gases from escaping.

(iv) Candidates should be aware that concordant titres are required before taking a mean. Some candidates suggested titration was the more accurate method as the decomposition may not have been complete, which contradicted their results in **(a)** and/or their answer in **(c)(i)**. Candidates should be encouraged to read through their answers to check that such contradictions do not occur.

Question 3

This proved to be challenging for many, though some excellent responses were seen. A common error was to omit testing the gases evolved. Candidates should be encouraged to read through the tests given in the paper and prepare suitable materials such as limewater, litmus papers and splints.

(a)(i) Almost all candidates observed effervescence but few went on to test the gas. Of those who did, some reported that the limewater ‘went cloudy’ without specifying ‘white’.

(ii) A sizable minority of candidates gained credit here. If a large excess of acid had been added in **(i)**, then candidates would have needed to add a large volume of ammonia to neutralise it before the white precipitate would have been affected.

(iii) Fewer candidates answered this correctly. A common error was to ignore the initial information that **FB 4** was the residue from **FB 1** and to start the equation with $NaHCO_3$.

(b)(i) This caused problems for many candidates. Most candidates correctly reported a blue precipitate with aqueous copper(II) sulfate but did not go on to describe the solution formed on adding acid as blue. More candidates gained credit for the white precipitate with aqueous barium chloride or aqueous barium nitrate being soluble in acid. Many candidates reported effervescence on adding acid to one of these precipitates but far fewer reported fizzing in both. Few candidates noted the change of colour of the methyl orange indicator to yellow or even to orange-yellow, with most writing ‘orange’ (incorrect) or ‘no change’ (incorrect as the solution would not remain colourless). Candidates should check whether there is a dotted or continuous line between tests as a significant minority used their coloured solution for the test with aqueous silver nitrate followed by nitric acid. The majority of candidates gained credit for the white precipitate with aqueous silver nitrate but few noted the precipitate was partially soluble in the acid. More candidates gained credit for noting the effervescence as the silver carbonate precipitate reacted with the acid.

(ii) It is important to report clearly at what stage in a test a reaction occurs. There should have been no reaction on adding aqueous sodium hydroxide and warming. The fizzing should only have been observed on adding aluminium. The majority of candidates wrongly claimed to have detected ammonia, which implies insufficient care as only the gas should have been tested. Very few candidates tested the gas for hydrogen.

(iii) A minority of candidates correctly identified the residue, with many selecting sodium nitrate even though this would have been thermally decomposed in **Question 2**. As methyl orange indicator was used in **Question 1**, candidates were expected to know that ‘acidic’ alone would be insufficient unless the indicator turned pink.

(iv) Few candidates gave a correct response, where ‘orange’ implied the solution is weakly acidic or neutral and ‘yellow’ that the solution is alkaline.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

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 ensure they have carried out the instructions given. Highlighting key words may be of assistance to some.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with regard to colour and state.
- Candidates should be instructed to complete the boxes relating to session and laboratory on the front of the paper, unless a single laboratory was used for the whole entry from the centre.
- In qualitative analysis exercises candidates should be careful to use the correct terms for e.g. precipitate and solution and also to describe colours precisely. The use of the Qualitative Analysis Notes is advised.

General comments

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This paper proved accessible to all candidates and it generated a wide range of marks. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Candidates completed the practical work to a generally high standard. Fewer candidates were able to gain full credit on the graphical section of the question. They should be encouraged to keep the scales simple and to read instructions carefully before drawing lines of best fit. The calculation was well executed in parts. Candidates need to be aware of what each term represents in the equation energy released = $mc\Delta T$.

(a) Almost all candidates recorded the balance readings in the spaces allocated. A high proportion of candidates in some centres did not give thermometer readings to the expected .0 or .5 °C and a significant number did not record the initial temperature of **FA 1** i.e. temperature at time = 0. Although a variety of temperature rises were recorded many candidates' temperature changes were sufficiently close to the supervisor's for credit for accuracy to be awarded.

(b) (i) Only a minority of candidates gained full credit here. The common errors seen included ignoring the instruction to extend the *y*-axis by at least 2 °C, writing the label on the *x*-axis as time / s when minutes were recorded, imprecise plotting of points and either ignoring the instruction to draw the second line of best fit for the **cooling** of the mixture or having points unbalanced. If a line is to be considered a line of best fit, it is expected that there will be an equal number of points on either side of the line, ignoring any anomalous points. Most candidates selected a sensible scale making their plotting more accurate.

(ii) Many candidates gave a correct temperature rise. Some gave the maximum temperature from the graph rather than ΔT. Some candidates drew additional lines on their graphs contrary to instructions. These were usually from the temperature at time = 2 minutes to the maximum temperature.

(c) Answers were generally expected to be given to two to four significant figures.

(i) A number of candidates clearly knew that they needed to use energy released = $mc\Delta T$ but used an incorrect value for *m* (generally the mass of solid).

(ii)(iii) Many candidates recognised that it was necessary to divide by 27 000 and then multiply by 106.

(d) A large number of candidates correctly stated that they had assumed that the impurity did not react with hydrochloric acid. A significant minority merely commented on the relative amounts of sodium carbonate and impurity.

(e) Many candidates correctly recorded the relevant data and obtained experimental results that demonstrated that they had completed the practical exercise accurately.

(f) Some candidates structured their calculations well to receive full credit.

(g) A number of candidates correctly ticked the first box. Better performing candidates explained their choice in terms of the significance of using a cooling curve.

(h) A significant minority of candidates realised that fewer moles of carbonate were used. Better performing candidates went on to explain the effect of this on the value of ΔH. It was insufficient merely to say that the value was smaller or larger, since this did not make clear the direction of change for a negative value.

(i) Many candidates correctly calculated the volume of hydrochloric acid but a number omitted or incorrectly used the mole ratio involved.

Question 2

(a) (i) The majority of candidates used silver nitrate to test for the presence of a halide. Very few dissolved **FA 4** before adding the aqueous reagent. Most did obtain a white precipitate and correctly concluded that the anion present was chloride.

(ii) A significant number of correct equations were seen but a number omitted or gave incorrect state symbols.

(b) It was evident that many candidates carried out the practical correctly; however credit was not always awarded as not all observations were recorded.

(i) It was necessary to note both the effervescence and the formation of a blue/green solution in the first test and then the blue precipitate and its dissolution in excess ammonia to give a dark blue solution.

(ii) Candidates generally were more successful in this part, with only the test with sodium hydroxide and aluminium really producing any significant difficulties. In this test, the ammonia is only produced after the aluminium has been added.

(iii) Where correct observations were recorded, most candidates were able to use this information to identify the cations.

(iv)(v) Better performing candidates realised the significance of the difference between anions that **were** present in **FA 5** and anions that **could** be present.

CHEMISTRY

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 ensure they have carried out the instructions given. Highlighting key words may be of assistance to some.
- Candidates should be aware of the difference between variables being proportional and being directly proportional.
- Results should be recorded, with correct headings, in the spaces specified.
- Candidates should be instructed to complete the boxes relating to session and laboratory on the front of the paper, unless a single laboratory was used for the whole entry from the centre.
- In qualitative analysis exercises candidates should be careful to use the correct terms for e.g. precipitate and solution and also to describe colours precisely. The use of the Qualitative Analysis Notes is advised.

General comments

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor’s results. This is achieved by centres returning the following documentation within each script packet for each session and for each laboratory within a session:

- 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.

This paper proved accessible to all candidates and it generated a wide range of marks. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

(a) Almost all candidates drew a suitable table in which to record their results. Some did not obey the rubric and carried out more or fewer experiments than the five that were specified in the instructions. Most included correct units with only the units for rate causing difficulties for some candidates.

A significant minority of candidates recorded their times to a higher degree of accuracy than was specified in the instruction – they should have been given to the nearest second.

Most candidates chose appropriate volumes of **FB 1** and of water to give a suitable spread of volumes whilst keeping the total volume of solution constant.

As expected, there was a large variation between different centres and between different laboratories in the same centre but when compared with the relevant supervisor, many candidates gained some credit for accuracy.

(b) Only a minority of candidates gained full credit. The common errors seen included ignoring the instruction that the origin should be included, reversing the axes, imprecise plotting of points and not drawing a line of best fit. If a line is to be considered a line of best fit, it is expected that there will be an equal number of points on either side of the line.

Most candidates selected a sensible scale making their plotting more accurate.

(c) Most candidates drew a line of best fit that was straight and corresponded to an increase in rate as the volume of **FB 1** was increased. For credit to be awarded it was necessary to specify the relationship as being directly proportional if the line passed through the origin.

(d) (i) Since the rubric for the question stated that construction lines should be drawn on the graph, for full credit these must have been clearly shown. Most candidates were able to convert the rate, from the graph, to calculate the time for the 15.00 cm^3 volume of **FB 1**.

(ii) A significant number of correct answers was seen. Some candidates did not calculate the **difference** between their calculated value and the 28 s given in the question.

(e) Candidates found this question challenging. It was necessary to recognise that the volume of **FB 2** should be doubled to 20 cm^3 but also to realise that in order to keep the total volume of solution constant, no water should be added.

(f) (i)(ii) Many correct calculations were seen but a significant minority of candidates omitted or reversed the effect of the stoichiometry of the reaction.

Question 2

(a) (i) The reactions involved in this section would generally be unfamiliar to candidates and acceptable descriptions of observations proved challenging to many. It was expected that all changes of colour and of state must be accurately described.

(ii) This question proved challenging. It was necessary to realise that the competing reactions affected how much of each reagent was available in each case.

(b) (i)(ii) Many correct observations were given but the observation must correspond to one of the precipitate colours so that, for example, 'cream/ white' as the only observation is not acceptable.

(c) (i)(ii) Some of the tests here were unfamiliar to most candidates so careful descriptions of the observations were needed. It was expected that candidates would realise the significance of the blue-black colour obtained when starch is added to iodine.

(d) (i)(ii) A number of candidates apparently struggled to decide whether some precipitates were soluble in excess reagents or not. Candidates should also realise that it is not appropriate to use sulfuric acid when testing for the presence of a sulfate.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- 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.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who had prepared well for the examination were able to attempt all of the questions. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

(a) (i) This question was discriminating. Some very good answers were seen. Others identified **X** (carboxylic acid) and **Z** (alkane) incorrectly or omitted a reference to intermolecular forces in their explanation.

(ii) This question was usually fully credited.

(b) (i) This was usually well known. Some candidates stated both isotopes for chlorine and bromine, which scored no credit.

(ii) This was found challenging by candidates. Some only stated the isotopes in the formula of the molecular ion omitting CH_2.

(c) (i) This mechanism was well known. Care was taken to correctly show the position of the arrows used to describe the movement of electrons as bonds were made or broken and the correct dipole present on the H–Br bond. Some candidates gave an incorrect intermediate or omitted the lone pair of electrons on the bromide anion.

(ii) Better responses gave a comparison between the relative stabilities of the primary and tertiary carbocation intermediates. Candidates are reminded that it is not sufficient to quote 'Markovnikov's law' by way of explanation.

(d) (i) Many candidates understood the idea of a partition coefficient but definitions often lacked precision. Candidates needed to include 'equilibrium' for full credit to be awarded.

(ii) Most candidates found this challenging. A common error was 1.22 (mass of **H** extracted when 100 cm^3 of the solution is used).

Question 2

(a) Candidates generally received full credit for this question.

(b) Full credit was often awarded. Common errors were for use of the ligand O_2H or for drawing two identical isomers.

(c) (i) Most candidates gave the correct expression. A common error for the units was $g^2\,dm^{-6}$.

(ii) This question discriminated well. Some very good answers were seen. Some incorrectly used 6.65×10^{-5} for $[Ca^{2+}]$ and $[C_2O_4^{\;2-}]$ or did not follow the question rubric to give their answer in standard form <u>and</u> to two significant figures.

Question 3

(a) Most candidates answered this well. The number of electrons for Cr was frequently incorrect.

(b) This discriminated well. Errors seen included equations involving $KMnO_3$ and K_6Mn.

(c) This was well known. Some candidates stated that light energy is emitted or did not mention that d-orbitals are split.

(d) (i) Many candidates gained credit here. Common errors were $[Cu(NH_3)_6]^{2+}$ and $[Cu(NH_3)_4(OH)_2]^{2+}$ for **B** and CH_3COOCu for **C**.

(ii) Candidates often gave the correct answer here.

(iii) Candidates who had answered **(d)(i)** correctly usually answered this well.

(iv) The observations for the reaction of calcium carbonate with an acid were not well known by many candidates. Answers referring to 'gas produced' were not sufficient.

(e) Candidates often gave an incomplete answer and omitted any reference to NH_3 being a neutral ligand or having no charge.

(f) (i) Most candidates correctly drew the structure of *trans*-platin. The shape and bond angle were less well known.

(ii) Most candidates gained credit. Some suggested that *cis*-platin is just bound to the cancer cell (without specifying DNA) acting as a marker.

(g) This question was usually fully credited.

Question 4

(a) The trend and its explanation were well understood by candidates.

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

(ii) Many candidates gained partial credit here though many thought that increasing the temperature would have no effect on the pH.

(c) Many fully correct answers were seen.

(d) This was well known by candidates.

(e) (i) Candidates often gave the correct answer here. Some used OH^- instead of water as the base.

(ii) This was a very discriminating question with some excellent answers but there were also many incorrect responses. Most candidates correctly calculated the initial moles of NaOH and CH_3COOH and a pH from their calculated $[H^+]$. Better performing candidates were able to calculate the equilibrium moles of the acid and salt.

(f) (i) Most candidates answered this correctly.

(ii) Most candidates identified a suitable indicator for each titration and gave a suitable explanation for their choice.

Question 5

(a) (i) This question was discriminating. Many candidates identified two or four peaks for **F** (instead of three), and three or five peaks for **G** (instead of six).

(ii) Most candidates answered this well. A common error was omitting the –OH group from their answer.

(b) This question was usually fully credited.

(c) Many candidates gained full credit here.

(d) (i) This was not well known. Some candidates incorrectly referred to strong C=C bonds or strong van der Waals' forces.

(ii) This was usually well known; some candidates did not refer to hydrolysis or light and just stated decomposition by bacteria or acid.

Question 6

(a) This was well answered by candidates. Some candidates drew a polymer and did not give the dipeptide, as requested by the question.

(b) This question was discriminating. Some very good answers were seen. Many candidates identified that valine would not move and lysine would move the most. However, in their explanations some only focused on charge or molecular mass as a reason for how far spots move and some suggested that lys and val-lys would have a different overall charge.

Question 7

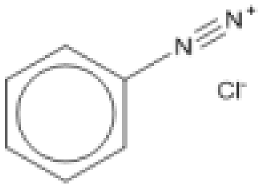
(a) This proved challenging for many candidates and answers often lacked clarity in the explanation. Candidates had to link the lone pair on X (C*l* or oxygen of the OH) being delocalised into the benzene ring with the C–X bond becoming stronger. Some candidates referred to the availability of the lone pair on X and the stability of the phenoxide ion, which were not sufficient.

(b) Many candidates gained full credit here.

(c) (i) This was answered well by many candidates. The common errors were to:

- heat under reflux in step 1
- omit concentrated in step 1 or step 2
- omit a temperature or heat in step 4.

(ii) This was well answered. Many diagrams were well drawn. The structure shown was a common error.



(iii) This question was usually fully credited.

(iv) Many candidates answered this incorrectly. The most common error was the equation shown.

$$C_6H_5NO_2 + 2[H] \rightarrow C_6H_5NH_2 + O_2$$

Question 8

(a) Most candidates sketched a line with a positive gradient. Only better performing candidates showed a vertical increase at the melting point with a continuous increase afterwards.

(b) Many candidates answered this correctly.

(c) Most candidates answered this question well. Common errors were –942 (360 used for C=O) and –182 (740 used for C=O).

(d) (i) Many fully correct answers were seen. A common error was –148 (no multiplication by 3).

(ii) This was well answered by candidates. Common incorrect responses included using incorrect equations or not dividing ΔS by 1000.

(iii) Most candidates were able to use their answer to **(d)(ii)** to predict the effect of increasing temperature on the feasibility of this reaction. Responses such as 'the reaction will not be feasible' were not sufficient.

(e)(i) This proved challenging for many candidates. The given equation was often unbalanced and/or had extra species present.

(ii) Many candidates answered this incorrectly. The most common error being +1.25 V.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

Good answers showed the following features:

- Clear drawing of chemicals, whether by displayed, structural or skeletal formulae. An understanding and correct use of the conventions involved in structural formulae is a major asset to any candidate.
- Precision when using curly arrows to describe mechanisms, in particular knowing and showing exactly where a curly arrow begins and where the arrowhead shows it ends.
- Understanding clearly what the steps mean in a calculation and displaying all working in full so that this understanding is communicated clearly and unambiguously.
- Keeping all decimal places on the calculator during calculations and then rounding correctly when the final answer is written on the answer line. This avoids the possibility of cumulative rounding errors.
- Adopting the conventions for 3D bonds used in the syllabus and then using them consistently and unambiguously.

General comments

The questions on the examination paper were generally well attempted by the great majority of candidates.

Candidates who performed less well are recommended to focus on some of the following areas:

- formulae are written in which plus and minus charges and other symbols, numbers or letters are clear,
- when changing an answer, candidates should clearly cross out the original and then write the new answer, clearly identified, in some available space on their script,
- correct use of full + or – charges, or the correct use of partial $\delta+$ or $\delta-$ charges,
- chemical equations should be correctly balanced.

Question 1

(a) (i) Many candidates did not associate a long retention time with stronger interactions with the stationary phase. Those who did so found the explanation, that alkenes and alkanes are non-polar, straightforward.

(ii) This was generally answered well. Many correct answers were seen.

(b) (i) This was often answered well. Some careless answers were submitted, including equations that produced either two positive ions or two negative ions as products.

(ii) There were many clear and accurate answers. The drawing of the intermediate, with the positive charge in the correct position, was done well. A small number of candidates did not show clearly that electrons from the C–H bond go back into the ring in the final step. This is an example of the need for precision in drawing curly arrows.

(iii) This discriminated well, with some correct equations given.

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

(ii) This was generally answered well.

Question 2

(a) Many correct answers were seen. The commonest error was Cu = [Ar] $3d^9$ $4s^2$.

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

(ii) This was generally answered well. Some diagrams for tetrahedral complexes were seen, which were not credited.

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

(ii) This was generally answered well. The outline of the octahedral complex helped many candidates, many of whom were able to draw two complexes that were mirror images of each other.

Question 3

(a) (i) Candidates found this question challenging. The formula of $[Co(NH_3)_6]^{2+}$ was not well known. Many answers were seen that were more like the copper complex e.g. $[Co(NH_3)_4(H_2O)_2]^{2+}$.

(ii) This was generally answered well.

(iii) Some good answers were seen in which candidates showed a clear understanding of the need to balance such equations for ligand molecules and for charge.

(iv) Most of the candidates who deduced **B** = $CoCO_3$ were able to go on to write an ionic equation for reaction 3.

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

(ii) Many good clear diagrams were seen, showing that the candidates were able to understand the name given on the paper and to convert it into a correct displayed, skeletal or structural formula. The errors seen on some scripts included a C=C bond in the middle of the structure between carbon atoms 2 and 3, and the missing out of the hydrogen atoms on the middle two carbon atoms.

(iii) This was generally answered well. Many candidates understood that use of the [O] convention requires the balancing of the equation for oxygen atoms.

(c) (i) Many good diagrams of planar structures were seen here. This was often done using no 3D bonds at all. Other correct renditions were seen that used the 3D bond conventions accurately. Some non-planar structures, some of them pyramidal and some of them tetrahedral, were also seen.

(ii) The best answers made it clear that the *cis*-platin binds to the DNA in the cells and that the consequence is that the cells involved are unable to undergo cell division. An alternative to the second part is that *cis*-platin binding to the DNA will prevent DNA replication. Some answers were seen that referred to preventing the spread of cancer, or the killing of tumour cells, which did not go far enough to gain credit.

(d) Accurate copying of the structure of the cyclobutane-1,1-carboxylate ligand was necessary and this accuracy was seen on many scripts.

Question 4

(a) The information, 'The oxidation number of nitrogen does not change' was given in the question; this was very important to the answering of this question. Candidates who appreciated this avoided writing equations that included HNO_3 or N_2. Some equations were seen that had CaO as one product; this substance cannot exist in an aqueous environment.

(b) This was well known and clearly explained by many candidates.

(c) This was generally answered well. Some candidates missed the instruction to, 'Complete the three arrows.'

(d) (i) The conventions necessary to show the correct answers, for example the use of square brackets and showing units as 'mol^3 dm^{-9}' rather than 'mol^3/dm^9', were used well by many candidates.

(ii) This discriminated well.

Question 5

(a) This was well known and clearly explained by many candidates.

(b) Many candidates found this calculation challenging. However, correct working out was seen on many scripts, so that it was often possible to award partial credit in some cases.

Some candidates explained clearly in words what each step in their calculation meant. It was easier to understand the candidate's purpose and to award credit in such cases. An example of this approach involves describing each line of the calculation as:

1. moles of Ce^{4+} in 21.8 cm^3
2. moles of NO_2^- that reacted with this
3. moles of NO_2^- in the 100 cm^3 in the volumetric flask
4. mass of $NaNO_2$ in the 100 cm^3 in the volumetric flask
5. purity of $NaNO_2$.

An approach like this might also have helped candidates to think clearly and to find their way through this calculation.

(c) (i) Some correct ionic equations were seen.

(ii) Candidates who had produced a correct equation often calculated the correct answer here.

(d) (i) This was generally answered well. The importance of the strong acid being completely ionised was stated on most scripts.

(ii) This was generally answered well.

(iii) This was generally answered well.

(iv) Candidates found this challenging.

(e) (i) The correct definition of buffer solution was known by many candidates.

(ii) Many good answers were seen. Some candidates struggled here and offered equations that included neither H^+ ions nor OH^- ions.

(f) (i) The information in the question, 'The reagent used is a copper(I) salt' was often missed. Many answers such as HCN and NaCN were seen.

(ii) Approximately equal numbers of candidates appreciated that reaction 2 is hydrolysis of the nitrile group and that reaction 3 is oxidation of the methyl groups on the ring.

(g) Candidates found this question very demanding.

Question 6

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

(ii) The reagent for step 1 was usually given correctly. The reagent for step 4 was rarely awarded credit. Many candidates suggested $LiAlH_4$, but this would reduce the –COOH group as well.

(b) (i) It was rare to see the correct amide product here. Many answers were seen that involved impossible rearrangements, or that did not match the given molecular formula.

More candidates were able to draw a correct structure formed when the **S** they had drawn was treated with $LiAlH_4$. An example of this was the drawing of **S** with an aldehyde group. This did not gain credit for **S**, but if **T** was then drawn with the aldehyde group reduced correctly to a primary alcohol group, credit for **T** could be awarded.

(ii) 'Condensation' was rarely seen for step **I** but many candidates identified step **II** as 'reduction'.

(c) Candidates should be warned that drawing a section of a polymer chain using skeletal formulae involves extra care. The 'continuation bonds' (i.e. the bonds to the neighbouring monomer residues) can easily be ambiguous, as they could either be continuation bonds or they could be methyl groups. Candidates who chose to use structural or displayed formulae did not encounter this difficulty.

Question 7

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

(ii) Many candidates used the information provided correctly to produce an accurate diagram of the repeat unit of the polyurethane Lycra®. No credit was given for copying the diagram of 'a polyurethane' at the top of the page.

(iii) The presence of hydrogen bonding in a structure such as Lycra® was deduced by a minority of candidates.

(b) A great variety of answers was seen here. The commonest correct answers were nylon, terylene, poly(ethyne) and superglue.

Question 8

(a) (i) The correct definition was not well known.

(ii) This was generally answered well. Many different correct answers were possible and many different correct answers were seen. Some carelessness was seen here, with incorrect equations being submitted.

(b) (i) This was generally answered well. 'Dot-and-cross' diagrams were clearly understood and reproduced accurately by the majority of candidates. Examples of errors include missing the lone pair on the nitrogen atom and missing all three lone pairs on the chlorine atom.

(ii) A common error for hybridisation was sp^2.

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

(ii, iii and **iv)**
More candidates now appreciate that when using the Gibbs equation, care is needed with units, as ΔH is given in kJ mol^{-1} while ΔS is given in J mol^{-1}.

A number of wrong renditions of the Gibbs equation were seen.

(v) Since ΔS is negative as T increases, $T\Delta S$ becomes a greater *negative* number. Alternatively, as T increases $-T\Delta S$ becomes a greater *positive* number.

(d) Many good answers were seen. This question required good chemistry, careful use of words and specific vocabulary. An example of this use of specific vocabulary can be seen in the marking point for recognising that basicity depends on the tendency of the lone pair to be protonated. It was also correct for a candidate to write that basicity depends on the tendency of the lone pair to receive a proton. By contrast, expressions such as 'basicity depends on the tendency of a substance to be attacked by a proton' were not accepted.

A few candidates assumed the question was about differences in acidity.

Question 9

(a) Some correct structures were seen.

(b) Candidates found this question challenging. The significance of the buffer pH being so close to the isoelectric point of cysteine and the consequent likelihood that cysteine molecules would exist in an uncharged state, was not often appreciated. Many candidates were able to deduce that glutamic acid will travel further than the dipeptide but were not able to go on to explain this answer clearly by reference to molecular mass.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- 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.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who had prepared well for the examination were able to attempt all of the questions. There was no evidence of candidates being short of time.

Comments on specific questions

Question 1

(a) (i) This question was discriminating. Some very good answers were seen. Others identified **X** (carboxylic acid) and **Z** (alkane) incorrectly or omitted a reference to intermolecular forces in their explanation.

(ii) This question was usually fully credited.

(b) (i) This was usually well known. Some candidates stated both isotopes for chlorine and bromine, which scored no credit.

(ii) This was found challenging by candidates. Some only stated the isotopes in the formula of the molecular ion omitting CH_2.

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(ii) Better responses gave a comparison between the relative stabilities of the primary and tertiary carbocation intermediates. Candidates are reminded that it is not sufficient to quote 'Markovnikov's law' by way of explanation.

(d) (i) Many candidates understood the idea of a partition coefficient but definitions often lacked precision. Candidates needed to include 'equilibrium' for full credit to be awarded.

(ii) Most candidates found this challenging. A common error was 1.22 (mass of **H** extracted when 100 cm^3 of the solution is used).

Question 2

(a) Candidates generally received full credit for this question.

(b) Full credit was often awarded. Common errors were for use of the ligand O_2H or for drawing two identical isomers.

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(a) Most candidates answered this well. The number of electrons for Cr was frequently incorrect.

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(iv) The observations for the reaction of calcium carbonate with an acid were not well known by many candidates. Answers referring to 'gas produced' were not sufficient.

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(ii) Most candidates gained credit. Some suggested that *cis*-platin is just bound to the cancer cell (without specifying DNA) acting as a marker.

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(ii) Many candidates gained partial credit here though many thought that increasing the temperature would have no effect on the pH.

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(e) (i) Candidates often gave the correct answer here. Some used OH^- instead of water as the base.

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(f) (i) Most candidates answered this correctly.

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(a) (i) This question was discriminating. Many candidates identified two or four peaks for **F** (instead of three), and three or five peaks for **G** (instead of six).

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(d) (i) This was not well known. Some candidates incorrectly referred to strong C=C bonds or strong van der Waals' forces.

(ii) This was usually well known; some candidates did not refer to hydrolysis or light and just stated decomposition by bacteria or acid.

Question 6

(a) This was well answered by candidates. Some candidates drew a polymer and did not give the dipeptide, as requested by the question.

(b) This question was discriminating. Some very good answers were seen. Many candidates identified that valine would not move and lysine would move the most. However, in their explanations some only focused on charge or molecular mass as a reason for how far spots move and some suggested that lys and val-lys would have a different overall charge.

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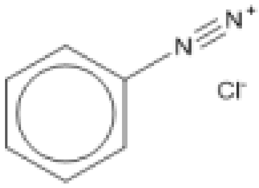
- omit concentrated in step 1 or step 2
- omit a temperature or heat in step 4.

(ii) This was well answered. Many diagrams were well drawn. The structure shown was a common error.



(iii) This question was usually fully credited.

(iv) Many candidates answered this incorrectly. The most common error was the equation shown.

$$C_6H_5NO_2 + 2[H] \rightarrow C_6H_5NH_2 + O_2$$

Question 8

(a) Most candidates sketched a line with a positive gradient. Only better performing candidates showed a vertical increase at the melting point with a continuous increase afterwards.

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(c) Most candidates answered this question well. Common errors were –942 (360 used for C=O) and –182 (740 used for C=O).

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(iii) Most candidates were able to use their answer to **(d)(ii)** to predict the effect of increasing temperature on the feasibility of this reaction. Responses such as 'the reaction will not be feasible' were not sufficient.

(e)(i) This proved challenging for many candidates. The given equation was often unbalanced and/or had extra species present.

(ii) Many candidates answered this incorrectly. The most common error being +1.25 V.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- The practice of writing answers in pencil and then going over in ink should be discouraged as it can make responses difficult to read.
- Candidates who perform well have good exposure to practical techniques through regular laboratory work.
- Candidates should avoid providing irrelevant information in their responses. This approach often leads to answers that contradict each other.

General comments

There was no evidence that candidates were short of time and the majority of scripts were complete. There were few ‘no response’ answers. Some candidates need to improve the legibility of their answers. The full mark range was seen.

Most candidates gave numerical answers to the required number of decimal places or significant figures.

There was a marked difference between numerical and chemical questions, where the numerical questions were better answered than the chemical questions.

In some responses, there was evidence of improvement required in basic chemical knowledge.

Candidates should be discouraged from non-specific responses such as ‘The temperature was wrong’ or ‘The candidate had an incorrect concentration’.

Comments on specific questions

Question 1

(a) (i) Quite a number of candidates considered water as a solvent rather than a reactant. Many wrongly thought that propanone served as a reactant. Only a few realised that the water could act as another nucleophile leading to an alcohol. There were many irrelevant statements e.g. ‘Dry propanone will not react with the bromoalkane or halide’, ‘propanone acts as a catalyst’ or ‘bromine is usually a liquid’.

(ii) The essence of this question was to relate the data to the high yield in the reaction. It was insufficient to say the position of the equilibrium was to the right – the question essentially states that already. The equilibrium shift to the right is driven by the sodium bromide precipitating out of solution due to its low solubility. Many candidates concentrated on the relative solubilities of the bromide and the iodide driving the equilibrium rather than the precipitation of one. Some candidates suggested that a high concentration of sodium iodide would push the reaction but there was no evidence of such a concentration in the question, only the low solubility of the sodium bromide (from precipitation) that would lead to a low equilibrium concentration of sodium bromide. Many candidates resorted to bond lengths, strength or energy or compound stability, which provided no answer.

(b) Many candidates found this challenging and list answers were common here. Some candidates offered a precaution that did not match their explanation e.g. ‘use a fume cupboard’ incorrectly linked to compound ‘flammability’. Sometimes the generic descriptions ‘harmful’ or ‘damaging’ were used instead of a specific term such as ‘irritating’. Some candidates included ‘toxic’ or ‘explosive’, which are not in the given list of hazards. ‘Heat’ is not the same as a naked flame nor is ‘keep away from flammable materials’. Many candidates stated ‘gloves’ and ‘goggles’, which were expressly excluded in the question. Also excluded were masks, as the question excluded protective equipment.

(c) (i) This was a straightforward calculation, requiring correctly quoting to two decimal places, at which virtually all candidates succeeded.

(ii) In order to assess the effect of the concentration of one reactant all the other variables need to be kept constant; many candidates did not recognise this. Most candidates correctly varied the volume of sodium iodide; many also wrongly varied the volume of 1-bromopropane. Others did not realise that the propanone volume needed to change in order to maintain a constant volume – essential in this type of experiment. Some had 50 cm^3 of sodium iodide, which would exceed the 42 cm^3 total volume limit.

(iii) Most candidates identified time as the dependent variable.

(iv) Most candidates also identified the reciprocal of time as a measure of the rate of reaction. Rate expressions that did not assume first order were also accepted.

(v) The major source of error is determining the time at which the cross can no longer be seen. Volumetric limitations were suggested but were not significant as were ‘not all the reactants were used up’. Some ingenious improvements were seen involving video recordings and colorimeters. Doing repeats does not improve accuracy, since each repeat would be subject to the same limits of accuracy. Suggestions such as ‘stir’, ‘use an indicator’ or ‘heat it up’ were irrelevant.

(d) This question proved to be challenging to the majority of the candidates and confused answers were common. It was not widely known that in an S_N1 reaction the rate determining step does not involve NaI but in an S_N2 it does. Some candidates thought there were two different rates in conflict or that the two rates were different. The tendency was to resort to a general rate statement, stereochemistry or other things to do with nucleophilic substitutions.

Question 2

(a) (i) The realistic way of maintaining a set temperature is by way of a water bath set at 40 °C. Temperature controlled immersion heaters were also accepted. Devices such as incubators or calibrated thermometers, which are impractical, or room temperature control (inefficient) were not accepted.

(ii) Many confused answers were seen in response to this question. A variety of reasons were given such as the ions move faster, a movement of electrons or temperature change (the question stated the temperature was maintained at 40 °C). The temperature at 40 °C would evaporate some of the water solvent leading to a change in silver ion concentration.

(b) Most candidates correctly calculated the values to two decimal places. A common error was quoting 1.00 as 1.0, giving the last three values in $-\log [Ag^+(aq)]$ to three decimal places and missing the negative sign in –0.18. A few miscalculated the values in the final column producing values that were out of the scale range on the grid. In this situation, candidates should be advised to recalculate the values.

(c) (i) The plotting of the data was done very well, with only a handful of candidates misplotting. The plotted points were indistinct in some responses. Sometimes the –0.18 value was plotted as positive and –2.56 as –2.60. The straight-line plot was very well done.

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(iii) Most of the candidates realised that the value for log C_{sat} would be the value on the *y*-axis, where the plotted line crosses a vertical grid line at a value of zero on the –log [Ag^+(aq)] axis. Many candidates were able to get the correct value of –4.55 at that condition. A similar number of candidates gave a value of –5.05, which is where the line crosses the axis at the edge of the grid (–0.5 on the –log [Ag^+(aq)] axis). Some candidates calculated a gradient. As the question asks 'Use your graph and equation...', reading two co-ordinates from the line and substituting into the equation was accepted provided the co-ordinates were on the line.

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(f) The unsuitability of a compound in a salt bridge is defined by whether it reacts with any of the other compounds present. Of the three compounds offered either of the chlorides would react with silver ions, so are not suitable. Their unsuitability also had to be defined in terms of the removal of silver ions from solution or by precipitation of silver chloride. Very often irrelevant or incorrect chemistry was given. Examples found were 'nitrate forms a precipitate with $AgCl$', 'nitrate because it does not contain the necessary chloride', 'nitrate ion will be deposited at the cathode' and 'nitrate will react with silver chloride'.

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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. It was apparent that many candidates did not recognise the simple techniques needed in **Question 1**.

- 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. One significant figure will usually be insufficient at this level.

- Candidates should be dissuaded from offering lists of answers beyond the number of responses asked for. This was evident in **Questions 1(c)**, **1(d)(ii)** and **2(e)**.

- 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.

General comments

Question 1 involved an unfamiliar experiment but used many typical A level techniques with which a candidate should be familiar. Therefore, it was important candidates read each sub-question carefully and applied their knowledge to the context of the experiment to fully appreciate what was required as an 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, ⊙, 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) A relevant description about solubility product was provided along with a statement that the lower the solubility product, the easier it is for a precipitate to form. However, it was evident that the concept of solubility product was not appreciated by candidates.

The first step required candidates to realise that Cl^{-}(aq) ions (from dilute hydrochloric acid) would precipitate Pb^{2+}(aq) ions as $PbCl_2$(s).

The next step involved deciding which metal ion would be easier to precipitate out, based upon the solubility product information given. As CuS had the lowest solubility product, it would be S^{2-}(aq) ions (from adding $(NH_4)_2S$(aq)) which would precipitate out CuS next, followed by adding of CO_3^{2-}(aq) ions (from $(NH_4)_2CO_3$(aq)) precipitating out $CaCO_3$(s).

Most candidates knew the first step, but both the order of addition of reagents and the identities of resulting precipitates proved difficult for many candidates, with multiple precipitations frequently seen in responses.

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(b) It was expected that candidates would write about ensuring all the ions had been reacted (or precipitated). Vague responses such as 'to make sure all the substance had been removed' received no credit as it was not clear which was the 'substance' being referred to.

(c) Most candidates gave a suitable reagent to neutralise any acid present and NaOH(aq) was by far the most popular choice. However, vague descriptions prevented credit being awarded for the test in many cases. A test needs a description of the test as well as the expected outcome. Thus 'use a pH meter' received no credit unless it was followed by 'and the pH will be 7'. Similarly, when indicators such as methyl orange were chosen, the colour indicating neutrality was needed.

(d) (i) Candidates with practical experience knew to heat the (solid) precipitate in a crucible with a labelled lid (to prevent loss of solid), using a Bunsen burner.

The other option available to candidates was to use a test-tube with heat proof method of preventing loss of solid. Glass wool would have sufficed here, but unfortunately cotton wool would have combusted so was not accepted.

Many candidates did not read the question, which asked about measuring the mass loss of a solid carbonate. Thus, those who opted to heat a solution in containers such as beakers or conical flasks disadvantaged themselves.

As the question talked about measuring mass loss, irrelevant methods of gas collection were not expected.

It was clear that many candidates did not appreciate that they were required to show how a thermal decomposition of a carbonate should be undertaken, as the erroneous use of a water bath as a method of heating was not uncommon – suggesting that some candidates had very little practical experience.

(ii) Most candidates were able to focus upon incomplete decomposition, but this four-mark question proved to be challenging for many. If the candidate did not appreciate how thermal decomposition should be done, they struggled to provide an answer.

The other significant problem was that a 'freshly filtered sample' was being heated and this sample would most likely still be wet. Fewer candidates picked up on this potential problem.

In either case, many candidates spotted a problem but did not state the effect on the calculated concentration of X^{2+}.

The erroneous ideas of further thermal breakdown of XO or of loss of waters of crystallisation due to heating were frequently seen.

Question 2

(a) (i) Relatively few candidates realised that this was a standard question requiring experimental based knowledge, that a large percentage error resulted from the weighing of small masses.

(ii) The large proportion of candidates knew how to make up standard solutions but there were significant numbers who did not.

The requirement to dissolve the solid sample in a small amount of *distilled* water in a beaker, transfer the resulting solution, with rinsings into a volumetric flask, make up to the mark with *distilled* water and mix thoroughly was known by many candidates. Candidates were required to describe the use of more than one volumetric flask, including a 1000 cm^3 volumetric flask.

Most chose to use the 1000 cm^3 volumetric flask as the first vessel, thus requiring a volumetric transfer of 10(.0) cm^3 into a 100 cm^3 volumetric flask and making up to the mark. Some very good answers were seen.

(b) (i) Many candidates omitted to plot the origin as one of the points. Many candidates opted to join the first and last points on this straight line of best fit graph. Candidates need to be advised that the joining of 'first to last' points is not necessarily the correct way to draw a line of best fit. Candidates need to realise that a line of best fit should have approximately the same number of points on each side (ignoring anomalous points).

(ii) Most candidates could read the co-ordinates correctly and calculate the gradient. A few did not ensure that their range covered at least half of the graph paper or that their answer was correctly rounded to three significant figures.

(iii) Nearly all candidates took a correct reading from their graph.

(c) (i) The key to this response was based upon the fact that hydrolysis of urea results in the formation of ions and this would increase until no more urea remained and thus the amount of ions in solution remained constant.

Every possible shape of sketch graph was seen, but most did get the correct shape, although many candidates stopped the line before it became horizontal. The explanations suggested that many candidates may have known the correct shape of the graph but could not explain why it had this shape.

Some candidates did not draw a suitable horizontal line due to 'excessive pencil wobble' and significant downward or upward slopes were seen after reaction completion time.

(ii) Most could take a correct reading from the graph. The scale proved a challenge for some candidates.

(iii) There were many excellent answers here. A significant minority added an unnecessary extra step into their calculation.

(d) This graph also relied upon the basic premise that the more ions in a solution, the greater the conductivity. Candidates were asked to sketch the graph and essentially, three straight lines were required based upon the information given: line 1, a straight line from the origin rising to any point at 300 s, line 2, a (near) vertical straight line at 300 s starting from where line 1 finished and line 3, a horizontal line starting from where line 2 finished. Most candidates sketched line 1 only.

(e) This was an example of candidates reading the context of the question and considering the information given. The expected precaution that the waste solution should not be put down the drain without suitable treatment due to the adverse effects of silver nitrate on the aquatic environment, was not appreciated by many. 'Wear gloves' was the common, irrelevant rather than incorrect, response seen. Often, candidates gave more than one precaution when only one was asked for.

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Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- The practice of writing answers in pencil and then going over in ink should be discouraged as it can make responses difficult to read.
- Candidates who perform well have good exposure to practical techniques through regular laboratory work.
- Candidates should avoid providing irrelevant information in their responses. This approach often leads to answers that contradict each other.

General comments

There was no evidence that candidates were short of time and the majority of scripts were complete. There were few ‘no response’ answers. Some candidates need to improve the legibility of their answers. The full mark range was seen.

Most candidates gave numerical answers to the required number of decimal places or significant figures.

There was a marked difference between numerical and chemical questions, where the numerical questions were better answered than the chemical questions.

In some responses, there was evidence of improvement required in basic chemical knowledge.

Candidates should be discouraged from non-specific responses such as ‘The temperature was wrong’ or ‘The candidate had an incorrect concentration’.

Comments on specific questions

Question 1

(a) (i) Quite a number of candidates considered water as a solvent rather than a reactant. Many wrongly thought that propanone served as a reactant. Only a few realised that the water could act as another nucleophile leading to an alcohol. There were many irrelevant statements e.g. ‘Dry propanone will not react with the bromoalkane or halide’, ‘propanone acts as a catalyst’ or ‘bromine is usually a liquid’.

(ii) The essence of this question was to relate the data to the high yield in the reaction. It was insufficient to say the position of the equilibrium was to the right – the question essentially states that already. The equilibrium shift to the right is driven by the sodium bromide precipitating out of solution due to its low solubility. Many candidates concentrated on the relative solubilities of the bromide and the iodide driving the equilibrium rather than the precipitation of one. Some candidates suggested that a high concentration of sodium iodide would push the reaction but there was no evidence of such a concentration in the question, only the low solubility of the sodium bromide (from precipitation) that would lead to a low equilibrium concentration of sodium bromide. Many candidates resorted to bond lengths, strength or energy or compound stability, which provided no answer.

(b) Many candidates found this challenging and list answers were common here. Some candidates offered a precaution that did not match their explanation e.g. ‘use a fume cupboard’ incorrectly linked to compound ‘flammability’. Sometimes the generic descriptions ‘harmful’ or ‘damaging’ were used instead of a specific term such as ‘irritating’. Some candidates included ‘toxic’ or ‘explosive’, which are not in the given list of hazards. 'Heat' is not the same as a naked flame nor is 'keep away from flammable materials'. Many candidates stated 'gloves' and 'goggles', which were expressly excluded in the question. Also excluded were masks, as the question excluded protective equipment.

(c) (i) This was a straightforward calculation, requiring correctly quoting to two decimal places, at which virtually all candidates succeeded.

(ii) In order to assess the effect of the concentration of one reactant all the other variables need to be kept constant; many candidates did not recognise this. Most candidates correctly varied the volume of sodium iodide; many also wrongly varied the volume of 1-bromopropane. Others did not realise that the propanone volume needed to change in order to maintain a constant volume – essential in this type of experiment. Some had 50 cm^3 of sodium iodide, which would exceed the 42 cm^3 total volume limit.

(iii) Most candidates identified time as the dependent variable.

(iv) Most candidates also identified the reciprocal of time as a measure of the rate of reaction. Rate expressions that did not assume first order were also accepted.

(v) The major source of error is determining the time at which the cross can no longer be seen. Volumetric limitations were suggested but were not significant as were 'not all the reactants were used up'. Some ingenious improvements were seen involving video recordings and colorimeters. Doing repeats does not improve accuracy, since each repeat would be subject to the same limits of accuracy. Suggestions such as 'stir', 'use an indicator' or 'heat it up' were irrelevant.

(d) This question proved to be challenging to the majority of the candidates and confused answers were common. It was not widely known that in an S_N1 reaction the rate determining step does not involve NaI but in an S_N2 it does. Some candidates thought there were two different rates in conflict or that the two rates were different. The tendency was to resort to a general rate statement, stereochemistry or other things to do with nucleophilic substitutions.

Question 2

(a) (i) The realistic way of maintaining a set temperature is by way of a water bath set at 40 °C. Temperature controlled immersion heaters were also accepted. Devices such as incubators or calibrated thermometers, which are impractical, or room temperature control (inefficient) were not accepted.

(ii) Many confused answers were seen in response to this question. A variety of reasons were given such as the ions move faster, a movement of electrons or temperature change (the question stated the temperature was maintained at 40 °C). The temperature at 40 °C would evaporate some of the water solvent leading to a change in silver ion concentration.

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