

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

There were some very strong performances on the paper with a high level of ability often evident.

Questions 2, 3, 4, 6, 7, 12, 15, 16, 24, 26, 29, 30, 34 and 35 were answered correctly by most candidates.

Questions 8, 17, 19, 31, 38 and 39 proved to be the most challenging with only the strongest candidates answering correctly.

Comments on specific questions

Question 8

The strongest candidates selected the correct answer, **A**. Approximately equal numbers of candidates chose each of the other three answers. This question was a matter of factual recall. It should be known that solid I_2 has a simple molecular lattice, therefore it can be deduced from the information in the question that solid CO_2 does too. Since solid SiO_2 has a giant covalent lattice the answer is **A**.

Question 17

This question proved challenging for many candidates. The most commonly chosen incorrect answer was **B**. The majority of candidates calculated the percentage of nitrogen in each compound correctly but did not recognise that the effect on the pH of the soil depends on the ammonium ion, which is acidic as it can donate an H^+ ion. Therefore, both compounds will decrease the pH of neutral soil.

Question 19

The most commonly chosen incorrect answers were **B** and **D**. If oxidation numbers are used it can be seen that neither oxidation nor reduction takes place in this reaction, therefore **A** is the only possible answer.

Question 31

This question proved challenging for most candidates. The most commonly chosen incorrect answer was **D**. For many candidates this question relied on whether or not a PH_3 molecule has a dipole moment. There is one lone pair on the phosphorus atom of the PH_3 molecule, so this molecule cannot be symmetrical; it is therefore polar.

Question 38

The most commonly chosen incorrect answer was **C**. Since the chlorine atoms are free radicals the bond breaking is homolytic not heterolytic. As chlorine atoms are not used up over the two reactions given in the question, they are acting as catalysts.

Question 39

This was the most challenging question on the paper with only the strongest candidates correctly giving the answer, **A**. The most commonly chosen incorrect answers were **C** and **D**. All three compounds have an $-OH$ group, so all will react with sodium to give hydrogen. None of the three compounds have either a methyl ketone or a methyl alcohol group, so none of them will give a positive iodoform test. It is possible for Z to be ethanoic acid, or pentan-3-ol, or propan-1-ol, making the correct answer **A**.

CHEMISTRY

Paper 9701/22
Structured Questions AS Core

Key messages

In questions where an explanation was asked for, a number of candidates gave a very general related comment rather than an actual explanation. For example, when asked to explain why sodium is a better electrical conductor than phosphorus, a significant number of candidates responded simply by stating that sodium is a metal whilst phosphorus is a non-metal. Whilst this is a true statement about sodium and phosphorus, it is not an explanation of conductivity.

Some candidates did not use relevant information in the stem at the start of a question. For example, in **3(b)(ii)** the question referred back to the equilibrium equation given in the stem of the question but many candidates made no reference to the specific equation and gave a very general discussion of the effect of pressure on equilibrium.

General comments

Calculations were generally well done; more in depth learning of organic mechanisms and their representation would have helped many candidates.

There were some issues with significant figures and candidates should remember that the number of significant figures in answers should match the precision of the data provided.

Comments on specific questions

Section A

Question 1

- (a) (i) There were some strong answers to this question. However, a number of candidates referred to the distance of the outer electrons from the nucleus being constant across the period; in direct contradiction of the trend of decreasing atomic radius being described. This trend should always be described in terms of the nuclear charge increasing across the period while shielding remains constant, with the attraction of the nucleus for the outer electrons increasing.
- (ii) Many answers revealed confusion between the terms *shell*, *subshell* and *orbital*. The key point being assessed in this question is that sulfur has a pair of electrons in the same orbital and it is the repulsion between these two electrons that reduces the ionisation energy; whereas in phosphorus all the electrons in the p subshell of the third shell occupy the orbitals singly.
- (iii) A positive statement was needed about each element in this answer; it was not enough to simply state that sodium has mobile electrons but that phosphorus does not. The term *delocalised* alone was not enough to explain conductivity; the key point is that the electrons are free to move throughout the structure.

- (iv) This question was generally well answered. Weaker candidates did realise that it is not the total number of electrons that matters but the number of delocalised electrons.
- (b) (i) These reactions and their products were recognised by most candidates, although MgNO_3 was often seen.
- (ii) Most candidates recognised that **X** must be a carbonate but many then chose CaCO_3 despite it being shown as (aq) in the flowchart.

Question 2

- (a) (i) This question was generally well answered.
- (ii) This was generally well answered, although ratios other than 1:6 were sometimes seen. In some cases, 2:6 was used, suggesting candidates confused dichromate ($\text{Cr}_2\text{O}_7^{2-}$) and chromium(III) (Cr^{3+}).
- (iii) This question was answered well by most candidates.
- (iv) There were many good answers to this question but there were a number of errors in the calculation of molar mass and a significant minority of candidates used the relative mass of iron.
- (v) This question was well answered by the majority of candidates.
- (b) (i) Many candidates did not recognise the term *ionic equation* despite one being given at the start of the question and so did not answer this question well.
- (ii) This was generally well answered, although state symbols were sometimes incorrect despite the information given in the question.

Question 3

- (a) (i) The dot and cross diagram was known by most candidates, although diagrams with no lone pairs or two lone pairs were sometimes seen. The shape of the molecule was frequently given as either 'planar' or 'bipyramidal'.
- (ii) This was not well known, with most candidates attempting to draw atomic orbitals of some form rather than the molecular orbitals (bonds) asked for in the question.
- (b) (i) This question was generally well answered but a common error was to refer to the forward and reverse reactions occurring at the same time, without mentioning rate.
- (ii) A common error was for candidates to make a general reference to the effect of pressure, in terms of le Chatelier's principle, but not to relate the general theory to the specific context of the question. A statement that the amounts of the reactants would increase as a result of the position of equilibrium shifting to the left (due to there being fewer moles of gas on the left of the equation) was needed.
- (c) Many of the sketches showed some confusion between the ideas of a Boltzmann distribution and an energy profile for a reaction. For those who attempted a Boltzmann distribution curve it should be noted that only one curve is needed to explain the effect of a catalyst; two curves are needed to explain the effect of temperature. The curve must start at the origin and must not touch the x-axis at the right-hand end.

- (d) This question proved challenging. In particular, many candidates did not realise that they needed to add curly arrows to the first part of the incomplete diagram and so attempted to start their answer in the central box. This needed to show the structure of the intermediate anion.

Candidates should be reminded that a curly arrow in a mechanism must always start either from a bond (touching the line in the diagram) or from a lone pair (which may need to be drawn, such as on the C of the cyanide ion and on the O⁻ of the intermediate in this case).

Question 4

- (a) All parts were generally well answered, although candidates should remember not to draw CH₃ groups when using a skeletal formula.
- (b) This question was generally well answered, although a number of candidates left the equation unbalanced.
- (c) This was generally well answered, although some candidates thought that acid rain is caused by sulfur vapour and did not mention that SO₂ is produced from the sulfur when the fuel containing sulfur is burned.
- (d) Some candidates did not appreciate that **G**, **H** and **J** referred to in this question had already been identified in the stem of the question and so made general references and guesses about their structures. Weaker answers did not explain the differences clearly enough. Many appeared to be confused about the various types of bonding and intermolecular forces, with covalent bond strength often thought to be related to melting and boiling points of molecular substances.
- (e) Some candidates were able to give the correct reagent and conditions for this reaction.

Question 5

- (a) (i) Stronger candidates recognised the effects of the differing reducing agents, with H₂/Ni selectively reducing the C=C but **not** the carbonyl, whilst NaBH₄ selectively reduces the carbonyl but not the C=C. Very few candidates recognised that **T** was triiodomethane.
- (ii) Very few candidates were able correctly to name **P**. Candidates should remember that such compounds with a double bond in the carbon chain can be named in the same way as when the chain is saturated but then to substitute '-en-' for '-an-' in the name.
- (iii) The majority of candidates gave good answers. Some candidates did not state that a precipitate is formed and just referred to the orange colour.
- (b) Successful answers worked through all of the information given and gave an explanation at each stage, before arriving at the final suggested answer.

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Paper 9701/33
Advanced Practical
Skills

Key messages

- Centres should be reminded of the importance of practical work and should provide candidates with examination practice throughout the course in preparation for this examination.
- Candidates should always read the rubric carefully to help them in answering the questions precisely as they have been set.
- Candidates should be reminded of the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- Candidates should be able to produce a graph with suitable scales and know how to construct appropriate lines of best fit.

General comments

This paper proved accessible to most candidates. Almost all candidates completed the paper indicating that there were no significant time constraints.

Comments on specific questions

Question 1

- (a) Almost all candidates recorded a suitable mass of magnesium and completed the table of temperatures. Many gave the temperatures as integers rather than to 1 decimal place. Generally, in spite of the possible variation of the mass used by the candidates and the supervisor, most candidates gave accurate values.
- (b) The most common error was in selecting a suitable scale as some candidates did not follow the instruction to include a temperature 10 °C above the maximum reached. In addition, many candidates did not use over half of each axis as stipulated in the current syllabus. Some labelled axes incorrectly, the most common error being 'time / s' with a scale of time in minutes. The plotting was generally accurate with most candidates giving clearly centred acceptable points. However, those choosing to use difficult scales such as 7 °C to one large square tended to be inaccurate in their plotting. A few candidates merely joined the points for the line of best fit. A substantial minority did not have an even spread of points either side of the line especially for the line drawn after the reaction was complete. A significant number of candidates gave the theoretical highest temperature rather than the theoretical rise in temperature as instructed.
- (c) Candidates should be encouraged to use the statement about the specific heat capacity of the mixture to help avoid carrying out the calculation in (i) using the mass of magnesium rather than the volume of solution. Most candidates gave the correct sign for the enthalpy change in (ii) and many carried out the correct calculation. A number of candidates gave their answers to an inappropriate number of significant figures.

- (d) Only the better performing candidates answered this well. The statement that the acid was in excess was not noted by many candidates. Common incorrect responses were that one of the acids was stronger than the other and that sulfuric acid contained two hydrogen ions so the enthalpy change would be twice that with hydrochloric acid.
- (e) This was answered well by the stronger candidates. Many answers did not include an explanation while others gave incorrect suggestions such as using a closed system or taking more frequent thermometer readings.

Question 2

- (a) Many candidates did not note the instruction to record burette readings for the rough titration. Many candidates used the correct headings for the accurate table of results. There are still many candidates who do not record their accurate burette readings to 0.05 cm^3 and some gave integer values. Candidates should continue with the rest of the question once they have obtained two concordant titres. A few carried out as many as seven accurate titres which could have had implications for the time available for the third question.
- (b) The majority of candidates calculated a suitable value of the volume of **FA 4** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to 2 decimal places.
- (c) Steps (i) and (ii) were correctly calculated by a majority of candidates. Many omitted the dilution factor in step (iii). Step (iv) proved challenging for many candidates as many answers given involved the sodium hydroxide in **Question 2** or did not use the mass of magnesium from **Question 1**.
- (d) Many candidates omitted the 'x2' when calculating the maximum percentage error in the burette reading. A few wrote the name of the apparatus rather than **FA 3** or **FA 4** on the answer line.

Question 3

- (a) Many candidates gave fully or partially correct observations for the tests with the alkalis, acidified aqueous potassium manganate(VII) and aqueous barium chloride or nitrate followed by dilute hydrochloric acid. However, fewer reported a brown gas when warming **FA 5** with hydrochloric acid so were unable to give the answer of nitrate. Most candidates correctly concluded sulfate was present in **FA 6**. Some candidates used incorrect terminology, for example describing a white precipitate as a "cloudy solution" while other candidates omitted the observation on using excess of the alkalis.
- (b) This part proved challenging for many candidates. Even when nitrite had been identified in (a), the statement that the anion in **FA 7** was in a different oxidation state was not incorporated into the test. A majority of candidates incorrectly used hydrochloric acid in step (i). Some of those selecting the correct reagents did not carry out the test sufficiently carefully as they reported red litmus changing to blue. Far more candidates gave a correct test in step (ii) but many of those using one of the aqueous barium salts did not report the white precipitate dissolving or partially dissolving in nitric or hydrochloric acid (or, unsurprisingly, in sulfuric acid). These candidates then concluded sulfate was present even though it would not have been in a different oxidation state from that in (a).

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Paper 9701/42
Structured Questions

Key messages

- Candidates should be reminded of the importance of showing full working in calculations.
- It is important that candidates do not round intermediate answers to only three significant figures, as this can sometimes lead to an inaccurate final answer. Unless otherwise stated, final answers should always be quoted to three or four significant figures.
- Candidates need to be vigilant when it comes to units. Units should be given for all dimensioned answers, and if the units are printed on the answer line, it is important that the units in the calculation correspond to those printed. This is especially relevant for energy calculations, where joules or kilojoules can easily be confused.

General comments

There was no indication that any candidate had run out of time whilst answering the paper, although there were a few candidates who hardly attempted any of the questions. Writing was for the most part legible and concise, although some of the workings in the calculations were a little confused.

Comments on specific questions

Question 1

- (a) Most candidates answered this question well. Almost all understood that the C^+ ion has one less electron than the C atom, and the C^- ion one more. Some candidates did not show that the 2p electrons are unpaired on the uncharged atom and the C^- ion. Other candidates incorrectly took an electron away from the 2s orbital to form the C^+ ion.
- (b) (i) Only a minority of candidates correctly stated that the hybridisation of the carbon atoms is sp^2 . Several thought it was sp^3 , whilst a number of candidates did not seem to understand the term *hybridisation*.
- (ii) Whilst many candidates correctly suggested $x = 60$, a large number of candidates suggested $x = 120$ or $x = 122$. It did not seem that the molecular structure of buckminsterfullerene was well known by candidates.
- (c) (i) Many candidates answered this question correctly. The most common errors were either to omit chlorine, and only concentrate on the catalyst/conditions, or to give the condition for reaction 1 as those for reaction 2, and vice versa.
- (ii) Most candidates answered this question correctly. The most common incorrect response was nucleophilic substitution.
- (iii) Many candidates appreciated that the compound with a fully substituted side chain $C_6H_5-CCl_3$ would be the product, although some suggested ring substitution as well.

Question 2

- (a) (i) Many candidates wrote a correct equation, although several omitted one or more state symbols. The most common incorrect answer was to write an equation showing the enthalpy change of formation.
- (ii) A number of candidates omitted state symbols from their diagram. The most common error was to miss out the atomisation of chlorine.
- (iii) Stronger candidates answered this question correctly; there were a number of incorrect answers with no working shown. Common errors included not using the bond energy of chlorine, or doubling it; using the ionisation energy of Cl rather than its electron affinity; and omitting the first ionisation energy of calcium.
- (b) Many candidates knew that the entropy of a gas increases with temperature, but fewer were able to explain this in terms of the gas particles gaining more energy, and thus able to distribute more energy quanta in a random manner.
- (c) (i) This was a well answered question. Most candidates understood that the change in the number of gaseous or in-solution particles was most important.
- (ii) The key point that the number of gaseous particles decreases during the reaction, was missed by several candidates.
- (d) This calculation was completed successfully by the majority of candidates. Some candidates either mixed up their signs, or did not multiply the entropies of hydrogen and ammonia by 3 and 2 respectively.
- (e) (i) Many candidates answered this correctly but some used incorrect equations such as $\Delta G = \Delta H + \Delta S/T$. Several also calculated the total entropy change, using the equation $\Delta S_{tot} = \Delta G/T = \Delta H/T - \Delta S_{sys}$. Some candidates who used the correct equation, did not understand that the units of ΔS are given in joules per mole per kelvin, rather than kilojoules per mole per kelvin.
- (ii) This was generally answered correctly. Some candidates thought that a positive ΔG indicated a spontaneous reaction.

Question 3

- (a) Most candidates answered this question well. The most common error was to form the ion by losing the 3d electrons before the 4s.
- (b) Only the strongest candidates answered this part well. Most candidates did not appreciate that in a tetrahedral complex the 3d orbitals split in a 3:2 ratio, rather than the (more usual) 2:3 ratio found in octahedral complexes.
- (c) (i) A significant number of candidates either thought the overall charge was 2+, or included charged Cl^- ions in their complex, but did not indicate the 2+ charge on Co.
- (ii) Only a minority of candidates drew structures that were clear. The use of wedged and hatched bonds in the drawing of octahedral structures needs practice if the drawings are to be clear and unambiguous. Many structures showed six groups surrounding the central Co atom, in either a regular or an irregular manner, without any indication of stereochemistry. A clear distinction between the 'fac' (all 'cis') and the 'mer' (two groups 'trans') isomers was required. Some candidates thought the two isomers were optical rather than geometrical and attempted to draw mirror images.
- (d) (i) The part was well answered by most candidates.
- (ii) This question was well answered by most candidates. However, weaker candidates thought the complexes were tetrahedral rather than square planar. The naming of cis-platin and trans-platin was not known by a significant number of candidates.

- (iii) The mode of action of cis-platin as an anti-cancer drug was known by only a small number of candidates.
- (e) (i) Many candidates incorrectly included the concentration of the solvent, $[H_2O]$, in their expression for the equilibrium constant. In other expressions, the concentration terms on the top or bottom were added rather than multiplied.
- (ii) Although most candidates were able to state that the larger the K_{stab} the more stable is the complex, they did not explain which complex they were referring to. Stronger answers clearly stated that the tetrammine complex was (significantly) more stable than the hexa-aquo complex.

Question 4

- (a) (i) and(ii) Most candidates answered well here but some suggested the reaction was second order in either one or both reagents.
- (iii) This was generally answered correctly. The most common errors were not using the same orders in the equation as were quoted in (i) and (ii), or leaving out the rate constant, k .
- (iv) This question was challenging for many candidates. The most common errors were not to include s^{-1} , or to suggest the units for a second order reaction were $mol^{-2} dm^6 s^{-1}$.
- (v) Many candidates correctly calculated the initial rate.
- (b) (i) Stronger candidates recognised that step 1 was rate determining, as this step included just one mole of each of the reactants, so ties in with the rate equation. If reaction 2 had been the rate determining step, the reaction would have been second order with respect to $[CH_3CHO]$, and first order with respect to $[OH^-]$.
- (ii) Only a minority of candidates correctly identified the role of CH_3CHO as an acid.
- (c) Stronger candidates correctly recognised the mechanism as nucleophilic addition. Weaker answers suggested nucleophilic addition-elimination, whilst others suggested electrophilic addition.
- (d) Most candidates correctly showed the δ^+/δ^- dipoles on the $C=O$ group, but often curly arrows were not clearly drawn. Stronger answers drew them from the lone pair to the $C=O$ carbon, and from the $C=O$ bond (rather than the C atom) to the O atom.

Question 5

- (a) (i) A wide range of metals were given by candidates in answers to this question. Many candidates had not considered relevant E^\ominus values. Metals with E^\ominus values more negative than $-0.41V$ were accepted, as long as they would not have reacted preferentially with water. Several candidates suggested Cu , Co or Ag , whilst others chose Fe^{2+} .
- (ii) Most candidates correctly calculated E^\ominus for their chosen metal, but fewer clearly explained how its value related to the feasibility of the reduction.
- (b) Many candidates did not choose the correct E^\ominus values. Either they used the $-0.41V$ of reaction 1, or they used the O_2/H_2O_2 value of $+0.68V$ rather than the correct H_2O_2/H_2O value of $+1.77V$.
- (c) This was well answered by the majority of candidates, who correctly calculated that the oxidation state of Cr is $+6$ in both compounds. Some based their argument on the number of oxygen atoms in the two ions, and either predicted a reduction (7 oxygen atoms going to 4) or an oxidation (3.5 oxygen atoms per Cr going to 4).
- (d) Whilst stronger candidates answered the calculation correctly, many other candidates did not appreciate that 6 moles of electrons are needed for every 1 mole of Cr deposited. Weaker candidates used the M_r of $Cr_2O_7^{2-}$ rather than the A_r of Cr .

Question 6

- (a) This question proved challenging for many candidates as it required the piecing together of many pieces of inorganic chemical knowledge. Stronger candidates recognised that since the oxides of **V** and **W** are both acidic, they must be in adjacent groups from the right hand side of the Periodic Table. Oxyanions with a charge of 2⁻ only occur with Group 14 or Group 16 elements, so **V** must be in Group 15 or Group 17. Finally, only sulfate forms a precipitate with Ba²⁺(aq) ions but not with Mg²⁺(aq) ions. Thus **W** is sulfur, and **V** could be either nitrogen or chlorine.
- (b) Only the better-prepared candidates answered well here. The dependence of $\Delta H_{\text{solution}}$ on both ΔH_{lat} and $\Delta H_{\text{hydration}}$ was known by several. A few were also able to explain that the determining factor is that $\Delta H_{\text{hydration}}$ decreases *more rapidly* than ΔH_{lat} on going down the group from Mg to Ba.

Question 7

- (a) (i) Although quite a number of candidates thought that ethanol was the more acidic, most correctly stated that phenol was the stronger acid. Some explanations were a little vague. The statement that “there is delocalisation in phenol” does not explain its acidity. Candidates needed to point out that it is the negative charge in the phenoxide ion that is delocalised over the π system of the benzene ring, and this spreading-out of charge makes the anion more stable than the ethoxide anion, where the charge is localised on the oxygen. Several candidates made the further point that the ethyl group in ethanol is electron-donating, and would thus destabilise the RO⁻ ion.
- (ii) Many correctly identified **E** as 2,4,6-tribromophenol, but several suggested 3-nitrophenol, or 2,4,6-trinitrophenol, for **D** (either 2-nitrophenol or 4-nitrophenol was accepted). The conditions for the tribromination, dilute aqueous at room temperature, were known by many, although several suggested the use of the Lewis acid FeBr₃.
- (iii) The majority of candidates named the mechanism correctly. However, several thought it was nucleophilic substitution.
- (b) (i) A number of candidates interpreted the word appearance as meaning what the formula looks like. Of those who described the substance’s actual appearance, common incorrect answers were brown, brown solution and cream.
- (ii) Many candidates correctly identified this step as diazotization, and so correctly suggested a temperature of less than 10°C. Some confused this with nitration and suggested concentrated acids at 55°C.
- (iii) Whilst many candidates recognised **G** as an azo dye, fewer were able to draw the correct structure. In many structures the –N=N– group was missing, or incorrectly drawn with a triple bond, or with + and – charges on it. Stronger candidates knew the orientation of the phenyldiazo group in either the 2– or the 4– position with respect to the OH group.
- (c) (i) Only a few candidates answered this question correctly. A number of candidates re-wrote the structure of **H** in a different way, or suggested structures of compounds having more than three different types of carbon atom.
- (ii) A number of candidates correctly identified the two methyl groups attached to carbon, but several suggested instead the methyl groups on nitrogen.

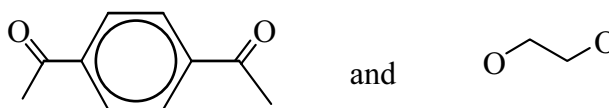
Question 8

- (a) It was not expected that candidates would identify **P** as a secondary amide but it was expected that they should identify **Q** as a ketone and **R** as a secondary alcohol.
- (b) The interpretation of the partial skeletal formula to determine chiral centres proved challenging for some candidates. Stronger candidates were able to identify that there is only one chiral centre at the secondary alcohol carbon. Several candidates drew circles around other carbons instead of, or in addition to, this one.

- (c) (i) Many correctly identified the amidic bond as the one broken by the hydrolysis reaction. Incorrect answers included the bond between the N and the ring; that between the O and the ring; the bonds either side of the secondary amine N; and the bonds in the methyl ketone.
- (ii) Most candidates who had correctly identified the amidic bond in (i) drew the correct structure of butanoic acid here.
- (d) Some candidates correctly described all the observations that would be made with each of these four reagents. Most candidates correctly suggested an orange precipitate with 2,4-DNPH, although some candidates suggested that the colour was red. Weaker answers suggested the (pale) yellow precipitate with alkaline iodine, but often gave an incorrect observation of a silver mirror with Tollens' reagent. The most common error was to suggest that Universal Indicator would turn red, indicating that acebutolol was an acid, rather than an alkali.
- (e) (i) Although some candidates correctly suggested LiAlH_4 as the reagent to reduce an acid to an alcohol, many candidates incorrectly suggested NaBH_4 or H_2/Ni . Weaker candidates mixed up reduction with oxidation, and suggested KMnO_4 or $\text{K}_2\text{Cr}_2\text{O}_7$.
- (ii) The question required the formula to be skeletal. Several candidates drew the structural formula of butan-2-ol, or did not show that butan-2-ol is the only C_4 alcohol to show optical isomerism, so suggested another isomer.
- (iii) The only two types of compound that fit with the observation given in the question are tertiary alcohols and carboxylic acids; quite a number of candidates suggested the latter. Butanoic acid or methylpropanoic acid were common incorrect answers.

Question 9

- (a) (i) Many candidates either included at least one polyalkene in their answer, or confused polyester and polyamide, and suggested, for example, nylon and terylene in that order. The most common correct answers were PLA and nylon-6.
- (ii) Almost all candidates correctly identified water as an appropriate molecule. Some candidates suggested HCl , which was also accepted.
- (b) (i) Stronger candidates were able to identify condensation polymers, which would be biodegradable, as opposed to addition polymers, whose C–C bonds are stable under biological conditions. Most candidates correctly suggested that **B** and **D** were biodegradable, but some did not recognise **A** as a polyester, or suggested that **C** would also biodegrade.
- (ii) Although many candidates correctly drew the diacid (or diacyl chloride) and the diol needed to form **B**, several merely split the polymer at the ester bonds, and draw the following, or variants on them.



- (c) (i) Many correctly identified **V** due to its having more $-\text{NH}_2$ groups than the other amino acids.
- (ii) Candidates did not appear confident in this area of the syllabus. The correct answer, 4, was given by only a small proportion of candidates. The most common incorrect answer was 2.
- (iii) Some candidates incorrectly suggested that the solubility of polypeptides in water is due to the hydrolysis of their peptide bonds, not appreciating that solubility is a physical phenomenon, during which no chemical change takes place. The correct answer, that polypeptides contain N and O atoms that can hydrogen-bond with water molecules, was given by a significant number of candidates.

CHEMISTRY

Paper 9701/52

Planning, Analysis and Evaluation

Key messages

Candidates should read the introduction to each question in order to make sure that they understand what is happening in the experiment.

Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus.

If one answer is required, then candidates should only give one answer, to avoid confusion.

Care should be taken in graph work to ensure clarity. Candidates are advised to show their points clearly by using a diagonal cross, 'x', with the intersect of the lines being the exact co-ordinates on the grid. Alternatively, a point within a circle, \odot , would be suitable, with the point being the exact co-ordinates on the grid. Candidates should be aware that a single point (with no circle) may no longer be visible if a line of best fit is drawn over it.

General comments

Although there were some strong answers, many candidates did not read the questions carefully enough and gave inappropriate answers which could not be credited. Candidates should be encouraged to spend time reading carefully to ensure they are clear about requirements.

Question 1

- (a) Many candidates did not realise that a volumetric flask was required for a standard solution. Others did not read carefully enough and gave many different pieces of apparatus rather than a type. On occasions, some candidates contradicted a correct answer with an incorrect one, such as a measuring cylinder.

In the calculation, many candidates failed to read that the mass of propanone to be calculated was for the volume of solution needed to match the volume of the apparatus chosen. Many candidates determined the mass of propanone needed to make up the 25 cm³ portion of solution used in the experiment and therefore were not awarded full credit.

- (b)(i)(ii) Stronger candidates realised that a reaction, however slow, would occur as soon as the two reactants were added and thus either reactant should be added last.

A significant number of candidates thought that no reaction would occur until the catalyst was added and consequently added the catalyst last.

- (c) (i) The correct answer was given by nearly all candidates. The volume, although not asked for, was correctly given by many. However, a few candidates incorrectly stated that a 25 cm³ pipette should be used to transfer 10 cm³ of solution.

- (ii) Only the best candidates gave the two correct reasons. Most candidates knew that NaHCO₃ would be preferred over NaOH because the effervescence stopping would indicate when the neutralisation was complete. However, some candidates suggested that NaOH would react with the propanone (to form iodoform) or would react with I₂. Many imprecise answers such as, "the NaOH would react with the solution / mixture" were seen from candidates who had not realised that the purpose of adding NaOH or NaHCO₃ was to react with the H⁺(aq) ions in the solution.

- (d) (i) Most candidates could do the second and third steps of the calculation, but missed the original dilution of 50 cm^3 to 100 cm^3 of reaction mixture. This meant that their final answer was 40 cm^3 , gaining only partial credit. Weaker candidates multiplied the volume of iodine by two.
- (ii) Responses suggested that many candidates had not studied iodine titrations as part of their course. Some candidates who recognised that starch would be a suitable indicator did not understand that the titration involved I_2 reacting with $\text{S}_2\text{O}_3^{2-}$ and gave the reverse colour change for the indicator. Weaker answers gave a variety of indicators such as methyl orange, methylene blue or phenolphthalein.
- (e) Many candidates misunderstood the question and gave calculated variables, such as concentration of iodine, as an answer.
- (f) This was answered correctly by most candidates.
- (g) (i) A significant number of candidates did not correctly label the graph in this question. Many incorrect straight lines were seen. The most common error for those who did produce a decreasing curve line was not to start from $t = 0$.
- (ii) Many candidates answered this question correctly.
- (h) Many candidates realised that temperature, whilst affecting both rate and rate constant, would have no effect on reaction order. Weaker candidates incorrectly stated that increasing temperature would increase rate and this, in turn, would alter the order with respect to I_2 .

Question 2

- (a) Nearly all candidates could convert the masses of ethanol into moles. However, some candidates could not use $mc\Delta T$ to calculate the energy transferred. The recording of the data was generally not done well. A number of candidates did not follow the instruction to give all answers to three significant figures. Many gave answers to three *decimal places* for the moles of ethanol. Others omitted the “trailing zero” so 0.00850 mol appeared as 0.0085 mol . Answers to the energy transfer calculation were frequently incorrectly rounded with many candidates not rounding up at all. Some candidates initially ended up with values which would not fit on the axes given in (b) and, realising that they had done something wrong, went back to recalculate.
- (b) Plotting the graph was generally done very well although there were some errors. The line of best fit lay very close to all points except the one anomaly. A number of candidates allowed the line of best fit to miss the points at 0.0148 and 0.0158 . Candidates should aim to get approximately the same number of points on each side of the line.
- (c) Nearly all candidates could identify the anomalous point. A very small number of candidates identified two anomalies or the wrong point.
- (d) Gradients were usually calculated correctly. Candidates should remember that at least half the width of the graph paper should be used in this type of calculation in order to maximise accuracy. A small number of candidates gave co-ordinates (y, x) and not as (x, y), and a small number of candidates incorrectly calculated $\Delta x/\Delta y$.
- (e) This was very well answered and nearly all candidates understood that the exothermic nature of the reaction was the reason.
- (f) (i) Most candidates could calculate the percentage errors although many rounded incorrectly.
- (ii) Only the very best candidates realised that the large actual percentage error between the experimental and theoretical values could not be accounted for by the low percentage errors in recording masses. Many candidates gained credit by explaining that heat loss accounted for the large discrepancy.