

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

This examination paper was a suitable challenge to the candidates.

Questions 1, 2, 5, 6, 8, 9, 11, 12, 19, 23, 29, 31, 32 and **35** were answered correctly by many candidates. Candidates found **Questions 15, 20, 22, 24** and **40** more challenging.

Comments on specific questions

Question 15

A significant number of candidates chose the correct answer, **B**. Approximately equal numbers of candidates chose each of **A**, **C** and **D**. When NaOH(aq) is added dropwise, the first precipitate to form will be the less soluble hydroxide, which in this case is magnesium hydroxide. When H₂SO₄(aq) is added dropwise, the first precipitate to form will be the less soluble sulfate, which in this case is strontium sulfate.

Question 20

The question focused on drawing the correct structural formula of 2,4-dimethylhex-2-ene, $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$. From this, candidates needed to recognise that there were two methyl groups on carbon atom 2 and as this was part of the $\text{C}=\text{C}$ bond, there was no cis-trans isomerism here. Stronger candidates noted that carbon atom 4 was joined to four different groups – C_4H_7 , H , CH_3 and C_2H_5 , so there was optical isomerism here.

Question 22

Approximately equal numbers of candidates chose each of the incorrect options **B**, **C** and **D**. Since the four reactant choices are all cyclic alkenes, and the product given has a ketone group and a carboxylic acid group, the reaction is oxidative cleavage of the $\text{C}=\text{C}$ bond with hot, concentrated, acidified KMnO_4 . The product has seven carbon atoms, **C** and **D** both have eight carbon atoms and neither of them has the $=\text{CH}_2$ group which would produce CO_2 . Candidates needed to look carefully at the positions of the two methyl groups in **A** and **B** to work out that the key was **A**.

Question 24

The most commonly chosen incorrect answer was **D**. Since compound X gives a positive result in the iodoform test it must have $-\text{CH}(\text{OH})\text{CH}_3$ in its structure, leaving **C** and **D** as possible keys. Compound X can be dehydrated to give two alkenes only. **D** would give three, pent-1-ene, *cis*-pent-2-ene and *trans*-pent-2-ene. **C** gives two, 3-methyl-but-1-ene and 2-ethyl-but-2-ene.

Question 40

The most commonly chosen incorrect answers were **C** and **D**. Candidates answered well by drawing structures. Structure **1** is produced when one ester link forms between two lactic acid molecules, which lose one water molecule. Structure **2** is produced when two ester links form between two lactic acid molecules, which lose two water molecules. Careful examination of Structure **3** shows it has only five carbon atoms. Carbon atoms are not lost in esterification, so Structure **3** cannot be an ester formed by two lactic acid molecules.

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<p>Paper 9701/22 AS Level Structured Questions</p>
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Key messages

- Candidates should be reminded to read questions carefully and to check answers thoroughly, especially in extended answers where more writing is required.
- Candidates should ensure they use chemical terminology accurately to remove ambiguity from responses and to ensure that their meaning is clear.
- Candidates are reminded to address 'explain' questions fully and not to just state facts. They should also show how these combine to give reasons for chemical phenomena.
- Candidates should ensure they show their working in calculations so that credit can be given for any correct working even when a final answer is incorrect.

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry.

There were sometimes errors with the appropriate rounding of numbers. These problems were seen often in **2(c)(iii)** and **2(c)(vi)**, but also in other questions. Candidates were often aware of the correct steps necessary for a correct answer but incorrectly rounded an answer before continuing with the next stage.

Responses were generally clear and well presented.

Comments on specific questions

Question 1

This question explored ideas of periodicity and the physical properties of elements across a period. Candidates' basic knowledge was good, but extended text needed to include specific vocabulary to gain maximum credit.

- (a) (i)** Some good answers were not complete, needing reference to the gas phase or moles.
- (ii)** Some stronger answers did not mention nuclear attraction for the electrons. Spin-pair repulsion incorrectly appeared in many answers.
- (b)** Most sketch graphs were correct, but were not supported by the text beneath. There was often no mention of electrons and/or the nucleus.

Question 2

This question covered several different topics within the syllabus. Several items looked at structure and bonding, with some quantitative, organic and physical chemistry to support the main theme.

- (a) (i)** Most candidates misunderstood the word "lattice", and described the hexagon/pentagon make-up of each C_{60} molecule, rather than detailing the supramolecular structure.

- (ii) This item proved challenging for many candidates. Many answers suggested that diamond has Van der Waals' forces between molecules. The strongest answers were very systematic and clear in making comparisons between one species and another.
- (b) (i) Many candidates omitted the word "only" from their answer.
- (ii) This item was answered well by most candidates.
- (c) (i) Some candidates gave more than one answer to this item which meant that credit could not be awarded where the alternative was incorrect.
- (ii) Many candidates incorrectly divided the mass by 12 or by 60, rather than by (12×60) .
- (iii) Many candidates did not correctly use p and/or V . Answers using $24 \text{ dm}^3 \text{ mol}^{-1}$ could not be credited. Early and severe or incorrect rounding was seen in many answers. A common error was to round 4.107 to 4.12.
- (iv) Many candidates who used 0.0024 mol for H_2 gained some credit, but many answers were confused. Again rounding was an issue and some candidates rounded their values doubly before giving the number of H atoms involved.
- (d) (i) This item was answered well by most candidates.
- (ii) Only the strongest candidates answered this question correctly.
- (iii) A range of state symbols were given, with (dil) often seen for both HCl and MgCl_2 . The incorrect MgCl was a common answer.
- (iv) Most answers were correct, but some rather unusual answers were also seen that had little relation to shape.
- (v) Most answers that managed to include SiO_2 gained credit here. H_2 was occasionally given as a product.

Question 3

This question also covered several different topics, using inorganic chemistry as the starting theme. Simple structural questions needed greater attention to detail. Knowledge of reagents and conditions was not always secure. Centres are advised to give candidates practise in writing ionic equations.

- (a) (i) There were some good answers to this item, but common errors included the incorrect formula for $\text{Ca}(\text{NO}_3)_2$ and sometimes NH_3 for nitric acid.
- (ii) Many answers gained at least partial credit for the role of CaSO_4 as a barrier. Few candidates completed the account by stating explicitly the lack of reactivity of CaSO_4 itself towards H_2SO_4 .
- (b) (i) This question was often poorly answered. Diagrams varied from those with only the outer shell to those without the 2+ charge, to those with extra electrons.
- (ii) This question was challenging for many candidates. A number of candidates drew 'dot-and-cross' diagrams instead, sometimes for the Ca^{2+} ion.
- (c) (i) This question was answered well by many candidates.
- (ii) Only the strongest candidates answered this question correctly. Some candidates did not appear to have read the question carefully enough. Many answers were correct except for the use of NaOH rather than OH^- . Cl^- was the most often omitted species.
- (iii) Many candidates answered this well.
- (iv) Many candidates neglected or missed the phrase "in terms of electron transfer", as a large number of answers did not involve a statement involving electrons.

- (d) (i) Many answers incorrectly had CaO as the formula for calcium hydroxide.
- (ii) Candidates' knowledge of reagents and conditions was generally secure, but KCN was often omitted from reaction 1 and reflux was sometimes omitted from reaction 2.
- (iii) This was generally well answered. "Redox" and "nucleophilic addition" were common errors.
- (iv) Many candidates gave descriptions of secondary alcohol formation from a ketone without mentioning the role of NaBH₄. Incorrect answers labelled NaBH₄ as a catalyst or oxidizing agent.
- (v) Candidates needed to say that the (four) different groups need to be *bonded* or *attached* to the central C atom. However many candidates missed this point. Other words such as "elements", "molecules" or "compounds" were not credited.

Question 4

Generally, knowledge of IR spectroscopy was very good in this organic chemistry question. This was also the case with free-radical substitution. However it was clear that a sizeable minority of candidates were not familiar with the material.

- (a) (i) There were many good answers to this item.
- (ii) The names of steps was quite variable and some odd chemical species were seen as products of each step. Several termination products contained correct structures but appeared to contain a double bond. Candidates should ensure that if marks are made in pencil and rubbed out, they can no longer be seen.
- (b) There were very many incorrect answers given to this item, including "substitution" and "condensation".
- (c) (i) "Concentrated" and/or "acidified" were most often missing from amongst the conditions regarding KMnO₄. When candidates named the oxidizing agent, many did not add the oxidation state information – *i.e.* manganate rather than manganate (VIII).
- (ii) There were many good answers to this item. Common errors included incorrect annotation or omission of the bond responsible for an absorption (*e.g.* CO₂H rather than CO₂-H or O-H in CO₂H). Some candidates identified an absorption at 2850–2950 cm for C-H in adipic acid without recognising that it would also be present in cyclohexene.

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Paper 9701/33
Advanced Practical Skills

Key messages

- Candidates should be advised to read the instructions given in the paper carefully. Underlining or highlighting key words would help some candidates to provide relevant answers.
- Candidates should be reminded that the line of best fit in a graphical question may be a straight line or a smooth curve.
- Candidates should be advised to consider the tests given in qualitative analysis questions and refer to the Qualitative Analysis Notes to help them in reporting their observations.
- Candidates should be reminded that in qualitative analysis, if a gas is evolved, a test should be carried out to identify the gas.

General comments

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

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

Every candidate must be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Also, Invigilators/Supervisors at Centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

This paper proved accessible to all candidates and there was a range of performance seen. Some stronger candidates answered very well. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Candidates were generally able to complete the practical work to a good standard. Questions involving graphical work rather than titration exercises were more challenging for candidates suggesting greater practice would be beneficial.

- (a) The standard of presentation of results was good and most candidates recorded their results in a single table. A number of candidates included the volumes of **FA 1** and **FA 2** which were not required as they were constant. The most common errors in the headings were to write 'sec' for 's' or to omit the unit for rate. While most candidates gave times to the nearest second as required, few recorded the thermometer reading to the expected level of precision. As with burettes, thermometers should be read to half a division at this level so all readings should be to .0 °C or .5 °C.

Most candidates calculated the rates correctly. Very few candidates ignored the factor of 1000 but more candidates rounded their answers incorrectly. Candidates should be reminded, for example, that $\left(\frac{1000}{31} = \right) 32.258$ is 32.3 to three significant figures and $\left(\frac{1000}{59} = \right) 16.949$ is 16.9 to three significant figures and 17 (not 17.0) to two significant figures.

- (b) A few candidates chose unusual scales and so had difficulty in plotting the points accurately. Relatively few candidates used large blobs in their plotting but greater care was needed by some candidates to ensure the point was in the correct small square and not simply on the nearest line. Very few candidates drew a smooth curve as a line of best fit even though the points indicated this was more appropriate. Candidates should be reminded that, as a rough guide, an increase in temperature of 10°C will double the rate of reaction. Only the strongest candidates gained credit for line of best fit as many candidates did not indicate all anomalous points. More candidates gained credit for extrapolating the line to 15.0°C with some anomalous points suitably indicated as given in the instructions. However, some graphs with straight lines of best fit made the extrapolation impossible.
- (c) Apart from drawing the line in an incorrect position, most candidates clearly understood the method needed. Some candidates did not convert their rates to times however.
- (d) Few candidates gained credit for this question by referring to the shape of the graph, for example positive gradient, or to the figures in the table of results. Many who did refer to the graph mistakenly said that direct proportionality was present. Only the strongest candidates commented on the greater increase in the rate with increasing temperature.
- (e) The majority of candidates gained credit for (i). The most common error was to use $M_r = 248$ instead of using the A_r values given in the Periodic Table. Some candidates gave the answer to an inappropriate number of significant figures. Careful reading of the question was needed in (ii) and (iii) with some candidates giving the initial concentration of **FA 2** rather than the concentration after **FA 1** had been added in (ii). In (iii) there was confusion about whether concentration or number of moles was being considered and which one to multiply or divide by 2.
- (f) The majority of candidates answered (i) correctly. However, there were a number of candidates where the time used in the denominator did not match any in the table. Many vague answers referring to the rate being lower in **Experiment 1** were seen in (ii) without the significance of this being explained.
- (g) Most candidates gained at least partial credit for this question.

Question 2

Candidates generally performed well on this question.

- (a) Most candidates did not note the instruction to indicate which tube was to be used for each test. Some ignored the fact that HZ was a monoprotic acid and tested with aqueous barium chloride or aqueous barium nitrate. Most candidates tested **FA 3** with aqueous silver nitrate as the first test but many did not specify adding ammonia to any precipitate formed. Candidates should be aware that 'no observation' is not an acceptable alternative to 'no (visible) reaction' or 'no (visible) change'. Almost all candidates suggested adding aqueous sodium hydroxide to **FA 3** but some did not include the addition of aluminium. Many candidates mentioned the effect on litmus but a large number did not make it clear that a gas/ammonia was responsible for the change in colour. Those candidates using the sodium hydroxide, aluminium (and warming) as **Test 1** were able to gain credit for **Test 2** by adding a named mineral acid or (aqueous) acidified potassium manganate(VII) as a test to distinguish nitrate and nitrite as they were not expected to know the relative strengths of nitric and nitrous acids.
- (b) Although almost all candidates wrote nitrate/ NO_3^- , some observations in (a) were incorrect or insufficient for a definite conclusion.
- (c) Overall this question was answered well with most candidates using the Qualitative Analysis Notes. However many candidates added aqueous sodium hydroxide and aqueous ammonia to excess. A large majority of candidates reported effervescence on adding **FA 3** to **FA 4** but few followed the instruction to test any gas evolved.
- (d) Most candidates selected hydrochloric acid or nitric acid and so gained credit.
- (e) Most candidates gained at least partial credit for this question and many gained full credit. The most commonly seen incorrect ions were Al^{3+} and Zn^{2+} although the observations in (c) generally did not support these choices.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates should be reminded to write clearly in black or blue pen and to make sure their work is legible.
- Candidates should pay attention to the command word and instructions in the question to make sure they answer the question as it has been set.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate knowledge and understanding of a wide range of chemistry topics. Calculations were generally well done and clearly set out.

The topic of mass spectrometry was not well understood.

Comments on specific questions

Question 1

- (a) (i) Most candidates answered this question correctly, describing the solubilities increasing down Group 2.
- (ii) Some candidates stated the factors (lattice energy, hydration energy, enthalpy of solution) without explaining how the variation of the first two factors affected the value of the last one. Some other candidates went into the details of why lattice and hydration energies decreased (due to increasing ionic radius), without relating the relative decreases in these values to the trend in the enthalpies of solution.
- (b) (i) Although most candidates answered this question correctly, common errors included not using square brackets to indicate concentrations or including $[\text{Sr}(\text{OH})_2(\text{s})]$ in the K_{sp} expression.
- (ii) Most candidates correctly calculated a value for K_{sp} , and included the correct units. A common error was to omit the 2^2 (= 4) in the calculation, for the $[\text{OH}]^2$.
- (c) (i) This was generally answered correctly but some equations were not balanced. A few candidates suggested the products were $\text{Sr}(\text{s}) + \text{O}_2(\text{g})$.
- (ii) Many candidates answered this question well. Common errors were to mention increasing atomic, rather than ionic radii, and not making it clear that it is the lesser polarisation of the anion that is important. Some candidates incorrectly described the polarisation of the carbonate ion, rather than the peroxide ion.
- (d) (i) Few candidates knew the correct decomposition equation and gave $\text{CO}_2(\text{g})$ and $\text{CO}(\text{g})$ as products. The most common error was to assume $\text{CO}(\text{g}) + \text{O}_2(\text{g})$ were produced. For this combination a balanced equation could be written. This was not possible for the other most common incorrect combination, $\text{CO}_2(\text{g}) + \text{O}_2(\text{g})$.
- (ii) Several candidates thought the colour change would be from purple to pink, rather than to colourless. Some candidates suggested pink to purple. Most identified that effervescence (or bubbles of gas) would be seen.

Question 2

- (a) This was very well answered and most candidates quoted the correct data from the Data Booklet.
- (b) (i) Although many candidates gained partial credit for either $\text{HCl} + \text{HClO}$ or $\text{HCl} + \text{O}_2$ as products, there was a significant number who wrote unbalanced equations, and some candidates who included H_2 or electrons.
- (ii) Many candidates used the E^\ominus value of -0.83 V for the $\text{H}_2\text{O} / (\text{H}_2 + \text{OH}^-)$ electrode rather than the correct $+0.89\text{ V}$ for the $\text{ClO}^- / (\text{Cl}^- + \text{OH}^-)$ electrode.
- (iii) Only stronger candidates were able to answer this question well. The increasing $[\text{OH}^-]$ would cause the $E_{\text{electrode}}$ for the ClO^- electrode to be more negative than its E^\ominus , so the overall E_{cell} would be larger, i.e. more positive. Le Chatelier arguments based on the overall equation were also accepted.
- (c) (i) This equation was generally constructed well but several included electrons on one side or the other.
- (ii) Most candidates calculated this E^\ominus_{cell} correctly.
- (iii) The most common error was not calculating the correct mole ratio for oxygen. 2O_2 or 3O_2 were often seen instead of 2.5O_2 .

Question 3

- (a) (i) Candidates calculated this pH well.
- (ii) Most candidates answered this question correctly. The most common error was omitting the lone pair on nitrogen.
- (iii) Only a minority of candidates described the hybridisation at both atoms correctly. The most common incorrect bond angle quoted was 104° .
- (iv) Many incorrect answers were given here. Candidates were often better at predicting the structure of **A** (CH_3NH_2) than that of **B** (HCO_2H).
- (b) (i) This question was well answered.
- (ii) Most candidates recognised geometrical isomerism, though some ambiguously stated stereoisomerism.
- (iii) Many candidates incorrectly thought there were three geometrical isomers. The stereochemical structures were often drawn incorrectly, with two wedge bonds and two ordinary bonds. The structures had to be clearly square planar (not tetrahedral) to gain credit.
- (c) Many candidates gave ionic species rather than compounds. Several recognised **C** as $\text{Ni}(\text{CN})_2$ but only the strongest candidates deduced that **D** and **E** were the potassium salts of nickel cyanide complexes, $\text{K}_2\text{Ni}(\text{CN})_4$ and $\text{K}_3\text{Ni}(\text{CN})_5$.

Question 4

- (a) (i) Many candidates understood the idea of a partition coefficient but definitions often lacked precision. Candidates needed to include equilibrium for credit to be awarded.
- (ii) This was generally well answered.
- (iii) Only the strongest candidates were able to predict that the K_{part} for butylamine would be nearer to 1 (i.e. larger than 0.416 or smaller than 2.4), because the butyl chain is not polar, and so would be more soluble in the organic solvent trichloromethane.

- (b) (i) Many candidates gained credit for identifying the lone pair of electrons on nitrogen as being the reason for the basicity of butylamine.
- (ii) This question was well answered. Either H^+ , H_3O^+ , HCl or H_2O were acceptable as acids.
- (iii) Many candidates knew that amides are much less basic than amines. Several candidates went further, and correctly stated that amides are neutral.
- (iv) Most candidates correctly suggested LiAlH_4 .

Question 5

- (a) (i) Although many candidates answered this question correctly, quite a number of candidates thought the chromium atom (in its ground state) was a $3d^44s^2$ system.
- (ii) Very few candidates knew that the +6 and +3 states were the two commonly occurring oxidation states.
- (b) (i) Most candidates knew that **H** was deep blue (or purple). Several candidates thought that **K** was green rather than yellow (yellow-green was accepted).
- (ii) Several candidates thought that **L** was a Co(III) and not a Co(II) compound.
- (iii) Candidates needed to give more than just the colour of **J**, i.e. blue precipitate.

Question 6

- (a) (i) Most candidates correctly identified **X** as an ammeter but voltmeter was a common error.
- (ii) The electrolyte **Y** needed to be a soluble silver salt. AgNO_3 was the expected correct answer but Ag_2SO_4 was accepted. Many candidates incorrectly suggested (the insoluble) AgCl .
- (b) The first two parts of this calculation were performed very well. However, using the electronic charge proved challenging for many candidates. At no point in the calculation should the Faraday constant have been used.

Question 7

- (a) (i) Most candidates correctly drew the repeat unit of addition polymerisation. For condensation polymerisation, there was often an extra oxygen drawn in the chain (i.e. the repeat unit had an oxygen at each end), and sometimes the repeat unit had an $-\text{OH}$ at each end. Several candidates forgot to include water as a product of the condensation polymerisation.
- (ii) In general, candidates had difficulty discussing ΔS , often equating it to stability rather than disorder. The recognition that ΔS for addition polymerisation would be negative (due to many gaseous molecules joining together for one polymer molecule) was better understood than the fact that in condensation polymerisation two molecules of (liquid) water are formed per one molecule of liquid diol used, so the ΔS is likely to be positive.
- (b) (i) Most candidates answered this question correctly. However, some did not distinguish between **R** and **R'** in their amide products.
- (ii) Some candidates answered this question well but a significant number did not include the O-H bond formed in the H_2O product. Some, however, included $2 \times \text{O-H}$ bonds being formed. In general, candidates should be aware that in almost all reactions, the same numbers of bonds are formed as are broken.
- (iii) The correct answer was given by many candidates but a significant number gave the incorrect sign.

- (c) In many answers the sign for ΔS was incorrect. Most candidates remembered to use the factor of 1000 to convert kJ to J.
- (d) (i) Most candidates knew the reagent, KMnO_4 , but fewer remembered the reaction should be heated.
- (ii) Many candidates answered this question well. However, several candidates thought that the tin was a catalyst rather than a reagent. Some suggested LiAlH_4 or $\text{H}_2 + \text{Ni}$. Neither of these allow a complete reduction of nitro group to amine.
- (e) Only the stronger candidates correctly identified the intermolecular forces and the groups involved. Ionic and dipole forces are not as important as van der Waals' (id-id) between benzene rings and hydrogen bonding between the N–H and C=O groups in amide groups in adjacent chains.

Question 8

- (a) (i) Many candidates identified only 5 or 6 peaks, rather than 7.
- (ii) Most candidates answered well here. Common errors were to suggest the C=O in amides (1640–1690) rather than in ketones (1670–1740), or to suggest the O–H in acids (2500–3000) rather than in alcohols (~3200–3600).
- (b) (i) In step 1, the reagent was often given as $(\text{CH}_3)_2\text{CCl}$, rather than $(\text{CH}_3)_2\text{CHCl}$. Either AlCl_3 or heat was often omitted. Most candidates thought step 3 would be effected by using hot KMnO_4 , forgetting that this reagent would also oxidise the prop-2-yl chain on the opposite side of the ring to $-\text{CO}_2\text{H}$. $\text{NaOH} + \text{I}_2$ was required, to be more selective. LiAlH_4 was needed for step 4, NaBH_4 is not powerful enough to reduce acids.
- (ii) This was generally well answered but a significant number of candidates suggested electrophilic addition, or nucleophilic substitution, for step 2.

Question 9

- (a) (i) The use of the $^{13}\text{C}:^{12}\text{C}$ ratio of 1.1% was required for this calculation.
- (ii) Many candidates correctly identified C_7H_7 as the correct formula.
- (iii) Although the molecular formulae were asked for, many candidates gave structural formulae (albeit correct) for **F** and **G**.
- (iv) Many candidates correctly identified **F** as benzaldehyde and **G** as phenylmethyl benzoate.
- (v) Only a few candidates correctly identified the aldehydic proton in **F** and the methylene protons in **G**. Many candidates did not attempt this question.
- (vi) Most candidates correctly recognised this as hydrolysis.
- (b) While many candidates gave the correct order of reactivity, some suggested that methylphenol was more acidic than benzoic acid. Few adequately explained that the enhanced acidity of benzoic acid is due to the negative charge on its anion being stabilised by delocalisation over two electronegative oxygen atoms, whilst the reason methylphenol is more acidic than phenylmethanol is due to the negative charge on its anion being delocalised over the benzene ring.
- (c) Most candidates did not follow the instructions to give a two-step route and merely suggested heating the acid and the phenol with concentrated sulfuric acid. Phenols are not nucleophilic enough to undergo esterification by the normal route.

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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. For instance, in **Question 1**, many assumed cyclohexane to be a solid. Candidates should also make sure they are clear about the answer required.
- Centres should include as much practical work as possible in the A Level Chemistry course so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates did not recognise the techniques involved in **Question 2**, which was a question based upon a very common practical.
- 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.
- When answering multi-step calculations, candidates should not round off numerical answers until the very last step as early rounding may introduce errors in the final result.

General comments

Question 1: The question was based upon an experiment candidates would probably not have encountered, but the individual sub-questions were based upon skills covered during typical practical work associated with A Level chemistry. The plotting and analysis of the graph was generally good but a significant number of candidates showed a lack of skill in this area. 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, ⊙, 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 probably not show up if a line of best fit needs to be drawn over it.

Question 2: This question was based upon a redox titration and it was apparent that some candidates had not seen this type of titration and the associated techniques of making up standard solutions. The more practical work a candidate carries out during their course, the better prepared a candidate will be for questions such as these.

Comments on specific questions

Question 1

- (a) Most candidates realised that a jacket of iced water (or just ice) was required to reduce the temperature of the cyclohexane to its freezing point of 6.5 °C. A common mistake was to have a level of coolant of insufficient height to ensure all the cyclohexane was surrounded by coolant.

Cold water alone as a coolant was insufficient to ensure freezing of cyclohexane and the use of liquid nitrogen as a coolant was not considered to be a technique commonly used in a school or college laboratory.

Some candidates could not be credited due to a lack of labelling of the diagram and centres are advised to discourage the use of 3D diagrams.

- (b) (i) The stronger candidates realised that a method involving dropwise addition of (liquid) cyclohexane was required. A significant number of candidates thought that a spatula should be used to transfer the cyclohexane, suggesting either that basic laboratory skills need improving or that the information that cyclohexane is a liquid had not been read.
- (ii) Most candidates were able to correctly calculate the volume of cyclohexane required. However, very few were able to state that a burette is unsuitable for measuring this volume and to provide an adequate reason. Many candidates thought a burette was suitable because it could be read to the nearest 0.05 cm^3 , 0.1 cm^3 or even the nearest 0.01 cm^3 . Other reasons for suitability were based upon the idea that a burette can hold 50 cm^3 , therefore 25.64 cm^3 could be measured. Others stated unsuitability but based their answers on the burette's precision being $\pm 0.5 \text{ cm}^3$ or even 1 cm^3 .
- (iii) The expected answer was that weighing by difference should be used. However, explanations as to why weighing by difference should be used, such as some of the solid remaining in the container, were accepted.
- (c) (i) Nearly all candidates were able to calculate the required values in the table. Some rounded to two significant figures, which happened to be three decimal places, suggesting there was some confusion between significant figures and decimal places. Some candidates even rounded to one significant figure, suggesting candidates thought values such as 0.01 were three significant figures. Some of the rounding was incorrect with values of 0.125, 0.475 and 0.575 being rounded to 0.12, 0.47 and 0.57.
- (ii) Most candidates were able to plot all the points successfully and produce a suitable line of best fit.
- (iii) Reading 8 was almost always identified as the anomaly but a correct reason for the anomaly was only given by the strongest candidates. Many assumed a lack of solute had been added or stirring had not taken place when, in fact, the decrease in freezing temperature was greater than expected and so more than 1.400 g had been added. Suitable alternative answers such as stating that the reading was taken (long) after freezing had occurred were accepted but unqualified responses such as "the reading was taken too late" were not.
- (iv) Most candidates successfully answered this question although a significant proportion of candidates stopped after the first step.
- (v) Answers to this question were generally good. A small minority of candidates did not take a large enough range (at least half of the graph) between co-ordinates or gave co-ordinates in the form (y, x).
- (d) Most candidates answered this question correctly.
- (e) Many candidates did not understand the term aromatic. Others thought that aromatic rings could contain 7 carbon atoms. Some thought that the molecule contained an additional oxygen atom and few suggested the presence of a nitrogen atom. Candidates should be advised that skeletal formulae are acceptable, but if used should not show hydrogen atoms bonded to the place a carbon atom is situated.

Question 2

- (a) (i) Most candidates calculated the concentration correctly.
- (ii) The first point, the relative formula mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, was carried out successfully by most candidates. The next step required the determination of the mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ present in 250 cm^3 of solution and this proved more challenging for many candidates. The third step involved scaling up the mass calculated in the second step (6.9475 g) by a factor of 100 : 8 and was only done correctly by the strongest candidates.

Although not asked for, a mass in a question like this (86.84) would normally be given to two decimal places, to match the accuracy of a typical laboratory balance but 86.8 g was accepted. Some candidates rounded to 6.95 in the second step which scales up to 86.9. Candidates needed to avoid unnecessary early rounding.

- (iii) This was challenging for a number of candidates. Many completed the first step and determined the number of moles of H^+ ions needed as being 0.04(00). However, in calculating the volume of $2.00 \text{ mol dm}^{-3} \text{H}_2\text{SO}_4$ needed, most candidates forgot to factor in that this acid was diprotic.
- (b) The marks available for this question should have indicated to candidates that a detailed answer was required, i.e. more than the preparation of a standard solution of iron(II) sulfate was required and involved more than the usual technique for making a standard solution from a soluble substance. Many candidates did not appreciate that after dissolving the iron(II) sulfate, the solid sand had to be filtered out and rinsed before transferring the filtrate to a volumetric flask. Also, many did not acidify the mixture before topping up to 250 cm^3 .

It appeared that many candidates had not come across the accepted procedure for preparing standard solutions from a solid.

Some candidates were unaware of the need for a volumetric flask.

Many candidates showed poor experimental technique by adding the solid directly into the volumetric flask and then attempting to dissolve it. Others decided to dissolve the solid in 250 cm^3 of (distilled) water before transferring this solution to the volumetric flask.

Many of the candidates who knew the correct technique did not state that distilled (or de-ionised) water should be used in both steps.

- (c) There were few correct answers to this question, suggesting that most candidates appear to have done few redox titrations. Many candidates gave the reverse colour change. Among those candidates who realised the end-point was when manganate(VII) ions appeared in solution, few were able to state that the presence of the first few manganate(VII) ions would make the mixture (pale) pink.
- (d) Many candidates needed to read the question more carefully here as a large number ignored the statement and tried to justify responses based upon the monoprotic and diprotic nature of the two acids or an incorrect assumption that there was a difference in acid strength. Very few candidates realised that the volume of $\text{MnO}_4^-(\text{aq})$ would increase as some would be used in the oxidation of $\text{Cl}^-(\text{aq})$ ions.