

CHEMISTRY

Paper 9791/01
Multiple Choice

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

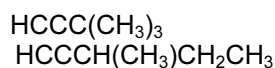
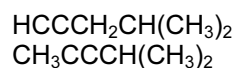
General comments

Questions **1, 8, 9, 13, 20, 21, 24, 32, 38,** and **40** proved to be the most accessible to candidates. These were non-calculation items requiring one or two pieces of factual recall. The most challenging questions were **5, 12, 17, 33, 35** and **36**. These were generally answered correctly by the stronger candidates.

Comments on specific questions

In **Question 5** many candidates choose the sodium/oil answers **A** and **D**. Of these, a number did not recall that white phosphorus reacts with oxygen in the air and picked **A**.

Question 12 asked candidates to work out the number of structural isomers of the unfamiliar hydrocarbon C_6H_{10} . This was option **D**: 7. Of the 7, 3 were linear and 4 branched. The latter were the most difficult to find:

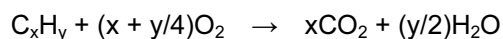


Question 17 proved the most challenging on the paper with the strongest candidates deducing, probably from drawing a dot-cross diagram, that each nitrogen atom had a lone pair of electrons which caused a non-linear structure having geometrical isomers.

In **Question 33** a number of candidates who chose **B** or **C** did not take into account that 72 g is 4 moles of steam. Other candidates realised this but gave the wrong sign (+) in their answer.

In **Question 35** candidates needed to calculate from the electrode equations that twice the number of electrons was needed in electrolysis 2 than 1. Since the time of electrolysis was the same, this would require twice the current, thus a current of $2a$ amps in electrolysis 2.

Question 36 required candidates to balance algebraically the standard equation for the combustion of a hydrocarbon, leading to answer **D** as in



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Paper 9791/02
Part A Written

Key messages

Candidates are encouraged to present their working clearly in calculation questions and to present longer written responses clearly.

General comments

The first two questions on the paper made for a fairly gentle introduction and were done well. Candidates' understanding and problem-solving were pushed quite hard in **Questions 3** and **6**, while the most challenging calculation of the paper was in **Question 7**. Candidates often quoted answers to calculations with an unreasonable number of significant figures that also revealed rounding errors from their working.

Comments on specific questions

Section A

Question 1

This question was intended to be a fairly easy opener and was done very well by candidates.

- (a) (i) Most candidates scored well.
- (ii) This part was done correctly by most candidates.
- (iii) Some candidates did not include the correct state symbol but this part was generally answered well.
- (b) (i) Most candidates appreciated that the NaCl dissolved to give a solution of pH 7, while the other two chlorides produced acidic solutions. Fewer candidates were able to specify a white ppt being produced with the hydrolysis of SiCl_4 . The most able candidates were able to describe misty fumes accompanying the hydrolysis of SiCl_4 and PCl_5 .
- (ii) This part was answered quite well, with greater success being seen with the first equation.
- (c) This part was answered correctly by most candidates.

Question 2

This question was intended to be fairly straightforward and was generally done well.

- (a) (i) The first dot-cross diagram was completed more successfully than the second, in which some candidates including the wrong number of bonding or lone pairs of electrons.
- (ii) This part was generally answered well; weaker candidates made general comments about radicals without referring to an unpaired electron.

- (b)(i) Stronger candidates gained full credit while weaker candidates described the atoms being produced in their standard states or from elements in the gaseous state.
- (ii) Only more able candidates got this part correct.
- (c) Many candidates were quite imprecise with their description of the energy changes involved, and in their comparison between them. However, candidates were given credit if they were evidently thinking along the right lines.
- (d)(i) This part was answered well.
- (ii) This calculation was answered well.

Question 3

This question was more demanding than most, discriminating the most able candidates. All but the strongest candidates got into a tangle in the final part.

- (a)(i) While candidates thought to make the energy gap between $n = 1$ and $n = 2$ larger than the gap between $n = 2$ and $n = 3$, some neglected to ensure that the gap between $n = 3$ and $n = 4$ was smaller still.
- (ii) Most candidates scored the mark for this question, but not those whose arrows did not definitely start and finish at one of the energy levels.
- (iii) Only the more able candidates recognised the significance of electron-electron interactions.
- (iv) Nearly all the candidates saw the need to divide by Planck's constant but many did not divide by Avogadro's number.
- (b)(i) This part was answered well.
- (ii) While most candidates realised the significance of the antibonding electrons in terms of the bond order, only the most able were able to relate it to a physical effect, i.e. the electric repulsion between the atoms. Some candidates knew that, in terms of energy, the antibonding electrons are more antibonding than the bonding electrons are bonding.
- (c) Many candidates asserted that only HF had hydrogen bonding. Some candidates who realised that both molecules could hydrogen-bond put the difference in the strength of these interactions down to the number of H-bonds that the molecules can form between each other.

Many candidates described the lithium halides in terms of van der Waals' forces, electronegativity or polarising power.

Candidates generally realised the significance of van der Waals' forces in bromine and its connection to the number of electrons in the molecule, but did not make a comparison with the hydrogen bonds of ammonia.

Question 4

Many candidates struggled with this question.

- (a)(i) A common response was to describe the sulfuric acid as a catalyst. It was also common for it to be written on both sides of the chemical equation, sometimes accompanied by 'conc'.
- (ii) Most candidates realised that sulfuric acid was acting as an oxidising agent here, but only the most able wrote the correct equation. Many candidates produced copper(II) hydroxide.
- (b)(i) This part was generally answered well.
- (ii) Many candidates were not clear enough in their responses to score all of the available marks. Candidates often referred to bonding and lone pairs without saying how many there were of each and omitted any mention of repulsion when explaining their reasoning.

Question 5

This question was generally answered well.

- (a) (i) Most candidates knew this definition.
- (ii) Again, many candidates scoring full marks, though some lost a mark for the state of water produced.
- (b) (i) Most candidates scored the marks for application of $q = mc\Delta T$ and converting the energy change into a molar one. However, most candidates struggled to deal with the 65% energy conversion: some ignored it while others multiplied rather than divided by 0.65.
- (ii) A surprising number of candidates answered this part in terms of heat loss despite the instruction in the question. Only the most able realised that incomplete combustion could be an issue.
- (iii) Generally this part was answered well.

Question 6

This question stretched the most able candidates and discriminated well between them.

- (a) (i) Most candidates answered this part correctly.
- (ii) Only the strongest candidates were able to provide a sufficiently exact definition to score credit.
- (iii) Many candidates were able to answer correctly.
- (iv) Only the more able candidates were able to appreciate the effect of the symmetry of the molecule on this problem.
- (v) Nearly all candidates scored at least one of these marks.
- (vi) Only the most able candidates were able to see the symmetry required to solve this problem.
- (b) (i) Many candidates answered correctly here.
- (ii) This part discriminated well. Weaker candidates made no headway while more able ones could find one of the structures. Only the most able found both structures.
- (c) Many candidates were able to draw the structures of the two isomers correctly though some drew the same molecule in two different ways. Candidates were generally successful in the positional aspects of naming the molecule but often slipped up with the geometric label.
- (d) (i) This part was generally answered well.
- (ii) Many candidates distinguished between the motion of the different ions towards the detector in terms of different acceleration rather than different velocity. Only the strongest candidates appreciated that ions of the same charge were accelerated up to the same kinetic energy; weaker candidates suggested that ions were differentiated according to their energy.

Question 7

This question combined a practical determination with a challenging calculation. It distinguished well between candidates.

- (a) (i) A surprising number of candidates suggested a recrystallisation, rather than just washing and drying the precipitate. Many omitted the final drying step.
- (ii) A few candidates slipped up with the molar masses but generally this part was answered well.
- (iii) Many answers were not entirely clear but credit was given for having the right general idea.
- (b) (i) A long calculation like this with lots of different chemicals involved definitely calls for the clear presentation of working. To a large extent, the clarity of this presentation correlated well with marks scored, especially error-carried-forward marks. Candidates who made it clear which chemical was the focus of which step were generally successful. Weaker candidates missed the 4:1 stoichiometry between thiosulfate and oxygen. Common errors were taking the RFM of O₂ to be 16 rather than 32, or forgetting it altogether. Another common error was forgetting to scale up the sample to a litre. A large number of candidates arrived at the correct answer of $4.10 \times 10^{-3} \text{ g dm}^{-3}$ yet omitted the 10^{-3} when transferring it to the answer line.
- (ii) The three marks for this part were successively harder to score and it discriminated well between candidates.

Question 8

This question tested practical planning and required an appreciation of how to calculate quantities relating to the method and the final result. It was generally answered well.

- (a) Most candidates scored the marks relating to insulating the reaction vessel, measuring initial and final temperature, and using appropriate apparatus to measure a stated volume of copper(II) sulfate solution. Fewer candidates appreciated the need to have a limiting reagent, and fewer still were able to present the calculations fully to show clearly how this was achieved. The hardest mark to access was the one relating to the need for continuous stirring during the reaction.
- (b) Most candidates saw the need to use $q = mc\Delta T$ to calculate the heat energy evolved. Only stronger candidates could explain properly what m represents and how it could be determined from the quantities and method of the previous part. A common error was not to make clear that the energy change is molar in the limiting reagent. Many candidates gave a method that would yield a positive value for the enthalpy change for an exothermic reaction.

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Paper 9791/03
Part B Written

Key message

Candidates are advised to consider all the information given in the question when constructing their answers.

General comment

Overall the standard achieved by candidates in this paper was good. Almost all candidates appeared to have prepared well for the examination. This was seen in their responses to the calculations in a number of questions and for kinetics in **1(c)(i)**, equilibria in **2(b)(i)** and **(iii)**, solid state in **3(a)(ii)**, and organic mechanisms in **4(a)**. Candidates found the calculations in **questions 2(c)(ii), 3(b)(i)** and the detailed explanation required for **3(b)(ii)** to be more challenging.

Comments about specific questions

Question 1

- (a) (i)** In general, this was well answered. Some candidates stated: that the molecules were elastic rather than their collisions; that the gas had no volume rather than the molecules have negligible size and; referred to an ideal gas having continuous random motion.
- (ii)(iii)** These were well answered; only a few candidates confused the two Laws.
- (iv)** In terms of the two sets of conditions, the most common error was to state that the temperature was high. When it came to the explanations, the idea of the importance of the intermolecular forces was more often stated than the idea of the size no longer being negligible. Some candidates stated both ideas for each explanation. A few candidates gave actual temperatures and pressures which were credited if they were reasonable and followed by the right explanation.
- (v)** This was not well answered. The order of the molecules was nearly always given correctly, though a few candidates did swap the order of CH_3Cl and C_2 . It was rare for candidates to progress beyond this point. Very few were able to assign the correct intermolecular force or then to compare the strengths of these forces. Most candidates answered only in terms of the size of the gas molecules.
- (b) (i)** This was well answered with only a few mislabelling the axes with incorrect labels such as rate, temperature, probability or frequency.
- (ii)** This was well answered; only occasionally was the maximum of the peak of the lower temperature curve not to the left of the printed curve.
- (iii)** This was not well answered and did not achieve the standard expected at this level. Relatively few candidates linked back to the curves and explained how the area under the curve above a labelled value of E_a related to the number of molecules with energy greater than the activation energy.

- (c) (i) This was extremely well answered with nearly all candidates able to explain how they had used the given data to arrive at the correct rate equation.
- (ii) The value of the rate constant was nearly always correct; the units were occasionally incorrect.
- (iii) Candidates found this slightly more challenging. Common errors involved using the stoichiometry of the equation to work out a value for n . This either gave n as $3(1.23 \times 10^{-3})$ or simply 3. Another common error involved not changing the units from dm^3 to m^3 with many candidates simply giving V a value of 1.00 in their equation.

Question 2

- (a) (i) Overall, this was well answered.
- (ii) Often responses were too vague to gain credit.
- (b) (i) This was well answered with only a few candidates providing a K_p expression or using round brackets.
- (ii) In general, candidates found this fairly straightforward; some candidates did not make a comparison of the K_c values stating instead that since $K_c > 1$ at the higher temperature then products must be favoured and so the reaction was endothermic.
- (iii) This was extremely well answered.
- (iv) Candidates found this to be quite a challenging question. Almost all candidates were able to see that the concentration of water at equilibrium would match that of the carbon dioxide; a reasonable number struggled to work out the concentration of the reactants once equilibrium was reached with many using the starting concentrations in their calculation. It is noteworthy that $/V$ was very rarely seen.
- (c) (i) All candidates performed the calculation with ease.
- (ii) Candidates found this a very challenging question. Candidates needed to let x equal the unknown amount of PCl_5 and then to set up an equation to be able to solve for the value of x . Most candidates had equations involving 12, which came from combining stoichiometric ratios from the equations at the start of the question.

Question 3

- (a) (i) This was well answered. A few candidates gave a value of 6, presumably either confusing the question with coordination numbers from complexes or by counting the surrounding spheres in the diagram given.
- (ii) This was well answered with almost all candidates able to annotate the diagram to show the three positions that were requested.
- (iii) Answers here were a little confused and often did not go into enough detail.

- (b)(i) Candidates found this question a real challenge with most responses not going beyond getting the correct values for the two relative formula masses. A few candidates approached the question as if it were an empirical formula question. They then reasoned that since the ratio of Sn:Cl was approximately 3:10 this meant there were one SnCl₂ to every two SnCl. This gave too approximate an answer.
- (ii) Candidates found this a very challenging question and very few candidates were able to use the data to discuss the ability of hydrogen and chlorine to oxidise tin. Many candidates attempted to calculate the combined reduction potential for Sn⁴⁺/Sn by simply adding the values or to discuss the feasibility of chlorine oxidising Sn to Sn⁴⁺ by looking at 1.36 – 0.15 – (-0.14). It was noteworthy that almost no candidate commented on the fact that the data referred to standard conditions when the reactions were very well removed from standard conditions.
- (c)(i) Although many candidates gave a correct structure, many gave answers that could not be correct.
- (ii) The trend to increase ionic character was identified by nearly all candidates; very few then linked this to the metal's electronegativity.

Question 4

- (a)(i) This was generally well answered. A few candidates did not appreciate that Br and CN needed to be in the axial positions of the transition state, while some did not give the correct bond angles for the trigonal bipyramid.
- (ii) Some candidates omitted to show the Br⁻ ion.
- (b)(i)(ii) Candidates found it a challenge to gain both marks in these two equations though many realised what needed to be the final products of (ii).
- (iii) Some candidates clearly recognised that the reagents would lead to hydrolysis within the same functional group level (FGL).
- (c) A large majority noted there was a reduction with a change in FGL from 3 to 1; fewer gave the initial identification of U. The most common error was to give the formula as C₃H₇CNH₂.
- (d)(i)(iii) Identification of the reaction mechanisms was well handled by the majority of the candidates.
- (ii) This was well answered with virtually all the candidates giving the correct skeletal formula.
- (iv) Candidates found this a challenging question with quite a few suggestions of PBr₅, HBr and a range of other incorrect reagents.
- (v) Almost all candidates stated ammonia; there were many confused conditions, suggesting use of aqueous solutions or the use of reflux.
- (vi) Nearly all candidates knew the identity of Y; some gave the atoms in an incorrect order or did not use brackets correctly.
- (vii) Some candidates did not remember to give both pairs of diastereoisomers.

Question 5

- (a) (i) This was very well answered.
- (ii) Nearly all candidates correctly identified each of the isomers; the explanations for the NMR spectra were often very muddled. Better performing candidates often gave a labelled diagram of the molecule and used this in their explanation.
- (b) (i) Many candidates linked the peaks to the presence in the molecule of ^{79}Br or ^{81}Br ; some did not link the relative abundance of these isotopes to the equal intensity of the peaks. A few candidates proposed the presence of ^{35}Cl and ^{37}Cl .
- (ii) This was very well answered.
- (iii) Most candidates got the two structures though some got them reversed. When it came to identifying the peaks, some candidates dealt with assigning 43 along with either 29 or 107/109. It appeared as if these candidates had not made use of the listing of the key peaks given above each spectrum.
- (iv) The mark for identifying C_3H_7^+ was awarded in most scripts; it was rare to see the rest of the equation given correctly. A common error was to see Br^- as a product.
- (c) (i) This was well answered; many candidates relied on drawing the skeletal formulae to work out each structural formula.
- (ii) Candidates found this a challenging equation. A reasonable number of candidates gave the correct formula but many omitted water as a reagent when it came to giving the correct equation.
- (d) (i) Many candidates struggled with this part and there were a wide range of answers. A common error was to suggest an ester for isomer 11.
- (ii) Overall, this was well done with most candidates using the Data Booklet successfully to give the correct ranges.

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Paper 9791/04
Practical

Key Messages

Candidates are encouraged to record their data clearly using the correct terminology and the appropriate precision.

General comment

The qualitative analysis question was particularly well done. In general, the recording of data in the tables for **questions 1(a)** and **2(a)** was well carried out. Candidates should check that they have the right form of words for the recording of information in tables, such as initial burette reading etc. The calculations were well handled, with all candidates coping well until it reached the most challenging parts. Practical results as judged by comparison of the answers to **question 1(a)** were all very impressive.

Comments about specific questions

Question 1

(a) The opening marks here were nearly always awarded, with almost all candidates drawing up a clear table for their results. A few candidates struggled in calculating the mass of the carbon dioxide that had been given off, with some subtracting the mass of the beaker and acid from the beaker and its contents after the reaction was over. This was seen only very rarely.

(b)(i)(ii)(iii)

These relatively straightforward calculations were all very well answered.

(iv) Many candidates noted that the impurity must not release a gas when reacted with acid; a few candidates gave more limited responses by saying only that the impurity would not react with the acid.

(c) (i) Most candidates reasoned correctly that the acid would no longer be in excess and so the amount of carbon dioxide released would therefore be less.

(ii) Candidates found this a challenging question. Some candidates continued along the same lines as they had used to answer (c)(i) and discussed whether the acid was in excess. Others presented percentage uncertainty calculations to compare a measuring cylinder with a burette. Relatively few candidates pointed out that the experiment relied on the difference of masses and so measuring the volume of the acid was not significant.

Question 2

(a) Overall, this was well answered with almost all candidates setting out their titration results in a clear manner. A few candidates did not record their readings to the nearest 0.05 cm^3 and gave all their data to only one decimal place. The repeated readings were nearly always close together, which showed that the candidates had a good grasp of this technique.

(b) This was well answered with almost every candidate able to select the correct titres to average.

(c) (i) All candidates performed this calculation with ease.

- (ii) The only error here came from a few candidates who used the wrong equation from the start of the question and so used the ratio of $\text{Mg}(\text{OH})_2$ rather than NaOH to HCl .
- (iii) This proved to be a much more challenging question. Many candidates did not realise that in this titration, the solution with the unknown concentration was in the burette so when they came to scale up to 1.00 dm^3 they thought that the moles of HCl from (c)(ii) was in 25.0 cm^3 rather than the volume they had given in (b).
- (iv) Nearly all candidates calculated the correct answer.
- (v) This was well answered; a few candidates did not follow the instruction and either did not use the given value of 81% when their percentage was greater than 90% or they did use the default value when their percentage was less than 90%.
- (vi) This was well answered with relatively few errors seen. These tended to involve either incorrect stoichiometry or relative formula mass.
- (vii) Candidates found this to be quite a challenging question and it was clear that some lost track here of exactly what they had calculated in the preceding parts. As a result, some carried out some of the calculations again or did not use the three values to which they had been directed.
- (viii) The main errors that were seen in the answer to this part were either to forget to use the ratio of 1:2 or more often to get the wrong relative formula mass of magnesium hydroxide by giving its formula as MgOH .

Question 3

- (a) (i) The observation that was most often missing was the effervescence that occurred.
 - (ii) This was well answered with almost all candidates noting that the solution decolourised.
 - (iii)(iv) This was well answered with candidates noting the colour of aqueous iodine in the first part and this then going blue-black on the addition of starch.
 - (iv)(v) In general, these were well answered; some candidates forgot to note the need to heat the solution in (iv). In both cases, it is important to stress that candidates need to give the full name or formula of a reagent and not write OH^- , for example, in place of sodium hydroxide.
 - (vi) This was well answered. A few candidates did identify Br^- after observing a cream precipitate with silver nitrate despite having a very clear indication of iodide from their observations in (a). When candidates suggested nitrate rather than nitrite this would often be linked to not observing the brown gas in (a).
- (b) (i)(ii) The observations here were nearly always accurate.
- (iii) This was very well answered.
 - (iv) This proved to be the most challenging question for candidates. Many responses were very uncertain about complexes and suggested that sulfate could act as a ligand and that this replaced nitrite when the acid was added.