

CHEMISTRY

Paper 9791/01
Part A Multiple Choice

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

General Comments

Four calculations were set, **Questions 4, 32, 36 and 40**. With the exception of **Question 4** candidates answered these well.

The questions candidates found most straightforward were **2, 15, 17, 20, 23 and 30**. These were non-calculation items usually needing only one or two pieces of factual knowledge to get to the answer.

Those found to be most testing were **4, 5, 11, 18, 22, 27, 29, 34 and 38**.

Comments on Specific Questions

In **Question 4** candidates gave a spread of responses, suggesting possible guesswork or incorrect balancing of the equation in this unusual calculation.

Question 5 also produced a spread of responses. Combining the two half-equations showed H^+ as a product leading to the correct answer.

In **Question 11** some candidates opted for **C**, not appreciating from the data and information given that the compound would be semi-metallic and not metallic.

In **Question 18** a significant proportion of candidates gave **A**, believing hydrogen halides were produced in all four equations.

Many candidates opted for **A** in **Question 22**, thinking that the C-H bond was broken by heterolytic fission.

In **Question 27** a significant number of candidates opted for **B** not realising the infra-red spectrum showed no $-OH$ group was present in the organic product.

In **Question 29** many candidates gave **C** or **D**. This implied all four carbon atoms were in the ring therefore the two CH_3 groups participated in hydrogen bonding.

Question 34 proved the most difficult of all. Only a minority of candidates deduced the original salt contained NH_4^+ ions and so needed CNO^- as the anion to yield only $CO(NH_2)_2$ on heating.

Question 38 centred on syllabus section **A4.3**. The spread of responses suggested guesswork was used by some candidates.

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Paper 9791/02
Part A Written

Key messages

Candidates who expressed working clearly in calculations were commonly the most successful and where a mistake was made they were able to pick up subsequent marks with the error carried forward. Some candidates were not drawing organic structures correctly, for example writing carbon atoms with dangling bonds to unwritten hydrogens, or showing all the hydrogen atoms in skeletal formulae.

Candidates are advised to look for clues in the question and be guided by them – especially where the context seems unfamiliar. They should also bear in mind that where a question is broken into several parts, the method for one part often follows on from the result obtained in the previous part.

General comments

The paper again discriminated well across the full ability range with many candidates making strong attempts at the most stretching question parts and showing evidence of being able to apply their knowledge in unfamiliar situations.

Comments on specific questions

Question 1

- (a) (i) This easy opener was answered correctly by nearly all candidates.
- (ii) While most candidates got this right, some were too vague, i.e. not specifying different *structures* of an *element*, to score the mark.
- (iii) Successful candidates drew a cycle and considered the connectivity of the atoms in P₄. Those who tried to obtain the answer through just directly combining the numbers without showing additional working often slipped up.
- (iv) This part was answered well.
- (b) (i) Many candidates did not refer to *gas phase* atoms, some referring to molecules instead.
- (ii) Some candidates answered that “effective nuclear charge” decreases down the group. This is not the case: attraction to the nucleus of valence electrons decreases down the group but the effective nuclear charge increases.
- (iii) This part was generally answered well.
- (iv) Most candidates correctly calculated the empirical formula, but a surprising number did not attempt to draw a structure.

Question 2

- (a) (i) Virtually every candidate answered this part correctly.
- (ii) It was a common error to draw the energy level of the products below that of the reactants. Similarly many ΔH arrows were double-headed.

- (b) Many candidates mixed up the terms *polarising* and *polarisable*. Another common problem was imprecise reference to bonding when careful distinction between the ionic bonding between the ions and the covalent bonding within the complex ion is required.
- (c) (i) Most candidates answered this part correctly.
- (ii) This part was answered well.
- (iii) Many candidates wrote “addition”.
- (d) (i) Most candidates scored this mark.
- (ii) Nearly all candidates correctly calculated the amount of excess HCl in the conical flask. However, many did not scale up from the conical flask to the bulk solution without introducing additional false steps.
- (iii) Weaker candidates could not manage to use the answer from the previous part to interpret correctly the back titration aspect. Others answered part or all of this part when attempting the previous part.
- (iv) Stronger candidates could see the link between this part and the previous one, and the stoichiometric relationship between the hydrogen ions and carbonate ions.
- (v) Only the strongest candidates answered this part correctly. More than one method was used to answer this question correctly – typically focusing on the masses involved or amount of substance. Those working through a stoichiometric mole approach often incorrectly identified the stoichiometric relationship between total metal ions and carbonate.

Question 3

- (a) Nearly all candidates answered this part (i) correctly. A few mixed up the letters in VSEPR. Close misses were credited, less recognisable attempts were not. Part (ii) was answered well.
- (b) Some imprecise answers were given to part (i). Stronger candidates referred to expanding the octet or otherwise referred to more than eight electrons in the outer shell. Part (ii) was answered well and, pleasingly, many candidates wrote sensible responses to this puzzle, showing an ability to apply ideas to novel contexts.
- (c) This part on the unfamiliar compounds of xenon discriminated quite well the stronger candidates.
- (d) While part (i) was answered correctly by nearly all candidates, part (ii) distinguished between the better candidates. Most candidates at least got the basic spatial relationships correct, though there were sometimes unrealistic hydrogen bonds shown. The weakest candidates did not draw the two bases correctly either side of the Janus wedge.

Question 4

- (a) (i) This part was answered correctly by the vast majority of candidates.
- (ii) The dangling bonds presented by some candidates lost them marks as they will be considered as methyl groups unless they penetrate large brackets or are shown as a dotted line.
- (iii) Many candidates got this part correct, through a fairly common error was to miscalculate the molar mass of cyclohexene.
- (b) This part was generally answered well, though in (i) some candidates used an incorrect formula of cyclohexene or wrote the equation as a substitution reaction and in (ii) some candidates did not draw organic structure properly.
- (c) Some candidates correctly drew the two isomers but went on to draw additional molecules that were the same but rotated on the page, negating their original responses.

- (d) Many candidates gave four structures, with only the very best candidates realising that two of them were the same meso compound. Some candidates were attaching two bromine atoms to the same carbon atom.
- (e) In (iii) most candidates correctly worked out the number of moles of X but only the stronger ones got the number of moles of Y correct. In (iv) many candidates simply changed the sigma bonds on the structure into dative bonds. Others added a dative bond to every sigma bond. Only the strongest candidates answered this part correctly, though many candidates got partial credit for valid dative bonds. The other parts were generally answered correctly.

Question 5

- (a) (i) Most candidates realised that “flammable” and “toxic” called for a fume cupboard and no naked flames. The suggestion of gas masks, given by a few, was not given credit.
- (ii) Some candidates gave vague answers about purification, but the majority got this part right.
- (b) This part was answered well though weaker candidates struggled with manipulating the density in the calculation in (ii) and some gave “catalyst” in (iii).
- (c) (i) Many candidates just received partial credit for referring to the slow reaction.
- (ii) This part was answered well.
- (d) Most candidates answered both parts correctly.
- (e) (i) Most candidates answered this part correctly.
- (ii) Few candidates answered this part correctly, many giving inorganic salts for their answer.
- (iii) The weakest candidates gave very vague answers to this part, but most realised that the exothermic reaction needed to be kept under control.
- (f) Nearly all candidates referred to the lower density of ethoxyethane compared to water, but surprisingly few commented on its low solubility in water. Few were able in (ii) to suggest the correct purpose of shaking with ethoxyethane.
- (g) Few candidates scored all of the marks in this question. The iodine mark proved to be the most accessible (though some wrote “iodide”) and, not surprisingly, the final part proved the most difficult. Hydroxy salts of magnesium were not allowed in the first part since excess acid had been added to the mixture.
- (h) This part was generally answered well.
- (i) Few candidates chose to filter or decant off the magnesium sulfate. While many candidates referred to boiling the mixture, only the stronger candidates made clear that the product should be *taken over* in a *distillation*, quoting a suitable temperature or range.

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Paper 9791/03
Part B Written

Key Messages

Success in this paper requires careful application of learning to the context of the question with, in particular, appropriate use of data given. A combination of specific recall of key ideas, as defined in the syllabus, together with the ability to apply ideas to more unfamiliar situations will be the mark of a successful candidate. The ability to explain ideas clearly is also crucial so as to avoid ambiguity in responses. It is also vital for candidates to recognise the need to answer the whole question rather than concentrating too much on a single idea within it.

General comments

This paper differentiated well across the grade range. Weaker candidates would probably have benefitted from making more use of the past papers so as to become familiar with the level of demand and the style of question.

The best responses were distinguished by their clarity where explanations were required notably in **1(c)(i)** and **(ii)**, **3(b)(iii)**, **3(c)**, **4(b)(i)** and **(ii)**. Weaker candidates tended to offer generic responses in these situations rather than making specific references to supporting data. These were questions where it was also necessary to make sure that the whole question was answered.

Comments on specific questions

Question 1

This question tested candidates' knowledge and understanding of basic ideas related to periodic trends, crystal structures and transition metal chemistry. It focused mainly on recall.

- (a) A significant number of candidates incorrectly referred to 'outer' electrons being in a d-subshell. A reference to 'valence' electrons was allowed but the key idea for several parts of **Question 1** was the realisation that the 3d subshell is 'inside' the 4s.
- (b) Electronic configurations were allowed ending in either $3d^{10} 4s^2$ or $4s^2 3d^{10}$ although the former is greatly to be encouraged especially with regard to the candidates' ability to answer questions such as **1(c)(ii)**. Subscripts were also allowed on this occasion but candidates should be encouraged to use the correct convention of superscripts to indicate the occupancy of each sub-shell.
- (c) In part **(i)** quite a large number of candidates did not actually explain their statements. Candidates needed to recognise the three parts to the answer – explaining the general upward trend in terms of **both** increasing nuclear charge and constancy of shielding; explaining the decrease between Mg and Al in terms of additional shielding from the full 3s (or higher energy level of 3p); and the decrease between P and S in terms of repulsion between paired electrons in the same p orbital. Part **(ii)** was where candidates were disadvantaged if they pictured the 3d as the outer subshell, as the relative constancy of ionisation energy needs explaining in terms of an increase in shielding with electrons being successively added to an inner subshell. This was a question where many candidates failed to recognise the need to answer the whole question with many failing to address the "slight general increase" in their answers.
- (d) Few candidates had any difficulty with this recall although a number of variations of the meaning of CCP were seen.

- (e) Another test of straight recall in part (i) was well answered by most and, similarly, most candidates remembered the 1:2 ratio of anions to tetrahedral holes in part (ii) although several failed to notice the statement in the stem that the cations occupied half of the tetrahedral holes.
- (f) The commonest problems here arose when candidates failed to recognise that **A** and **B** were compounds while **C** and **D** were complex ions (i.e. charged)

Question 2

This question tested the application of ideas and calculations related to gases, free energy and entropy as well as rates and the relationship between rate equation and mechanism.

- (a) Most candidates recognised that the earlier equation given for UDMH served as a clue to the outcome of reaction between hydrazine and dinitrogen tetroxide.
- (b) Most candidates remembered this definition correctly although it must be remembered that a reference to 'standard conditions' is essential in such a definition.
- (c) The main errors seen here were in part (iii) when many candidates failed to convert the given value for the entropy change into $\text{kJ K}^{-1} \text{mol}^{-1}$. A failure to respond to the requirement for a one decimal place answer also cost some marks.
- (d) These calculations were generally done well although a significant minority assumed that all 244 kg was UDMH.
- (e) Quite a large proportion of candidates failed to recognise that the equation given was in the format $y = mx + c$ and so failed to base their calculation on a gradient determination. Many of those who did calculate gradient used the first and last points on the graph but failed to notice that the horizontal axis did not start at zero and so divided by 0.0015 instead of by $0.0015 - 0.0010$. In part (iii) a specific reference to the involvement of **two** NO_2 in the rate determining step was needed to establish the link with the rate equation.

Question 3

The contrasting choice of conditions required to bring about elimination or nucleophilic substitution in the reaction of a halogenoalkane and alkali is a 'classic' context and formed the basis for this question, which also developed a comparison of the $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ mechanisms.

- (a) In part (ii) the most common mistake was a reference to 'high' temperature – this mistake probably arising from the fact that it is common to say that elimination is favoured over substitution by 'higher' temperatures. However, given that the boiling point of the solvent, ethanol, is 78°C , refluxing the reaction mixture should not be referred to as a 'high' temperature. In part (iii) marks were lost by many who ignored the instruction to give displayed formulae – although consistent skeletal or 'semi-displayed' formulae could earn 2/3 – and also by candidates who overlooked the possibility of *cis/trans* isomerism and offered methylpropene as the third alternative.
- (b) Most candidates recognised the need for aqueous conditions in part (i) and also produced good responses to the mechanism in part (ii) although the Br^- was often omitted. The fact that five marks were available in part (iii) encouraged most candidates to develop their answer here with the explanation needing to state that $\text{S}_{\text{N}}1$ was the one that produced an optically **inactive** product due to the **planar** intermediate, leading to attack from **either** side and thus a **racemate**, while $\text{S}_{\text{N}}2$ involved **inversion**. In part (iv) most candidates recognised that the product would be (*R*) due to the inversion but many failed to include a (+) or (–) – either of which was accepted as inversion of configuration does not necessarily create opposite optical activity.
- (c) Most candidates were able to produce an explanation here based either on steric hindrance of the tertiary halogenoalkane preventing the attack necessary for $\text{S}_{\text{N}}2$, or on stabilisation of the carbocation by the electron-releasing effect of three alkyl groups.

Question 4

A question based on gas equilibria, Le Chatelier's principle with a section related to fuel cells and a quantitative electrolysis calculation.

- (a) It was pleasing to see that the vast majority of candidates avoided the most common mistake of including square brackets in their answer to part (i). In part (ii) answers expressed as fractions were allowed on this occasion but the practice should be discouraged and a mole fraction should always be given as a decimal to an appropriate number of significant figures. In part (iii) it was surprising how many candidates failed to include the pressure in their calculation despite having included a 'p' in their expression in part (i). It is clear from the answers to part (iii) that the idea of a dimensionless equilibrium constant, as defined in the *Data Booklet* (and referred to in syllabus section B1.5(c)) is causing some confusion. In the *Data Booklet*, [X] is defined as the concentration of X divided by the standard concentration, such that all the values used in calculation of an equilibrium constant, and therefore the constant itself, have no units. This is a different approach to that taken in A level syllabuses. If that definition is extended to the idea of K_p , then the given pressure of 7500 kPa should be divided by 100 kPa (that being the standard pressure in kPa) to give '75' to be used in the calculation of K_p . On this occasion, the frequency of confused responses meant that answers based on $p = 7500$ or $p = 75$ or $p = 7500000$ were accepted but the correct approach will be looked for in future calculations of this type.
- (b) In both parts of this question the quality and clarity of explanations was key, with candidates needing to make clear that elevated temperatures (in part (i)) and pressures higher than atmospheric (in part (ii)) are used to increase reaction rate in **both** steps of the process, before they discuss the impacts on equilibrium position and yield in terms of Le Chatelier's principle.
- (c) The equation in part (i) was well done but that in part (ii) was often reversed or unbalanced. When calculating the cell potential a surprising number of candidates multiplied up the electrode potentials (as if they were enthalpy changes) and/or added the two electrode potentials together. The key idea to be remembered is that a cell potential represents the **difference** between the electrode potentials.
- (d) Many candidates over-simplified the half-equation for the cathode reaction by omitting the ammonia.
- (e) This calculation proved to be a good discriminator with weaker candidates unable to find their way through the steps required despite the syllabus statement B1.5(i).

Question 5

A fairly typical organic chemistry question aiming to test what should be familiar chemistry although, again, the clarity of explanations is key.

- (a) Candidates need to be careful about over reliance on 'stability' as an explanation of something. The key idea needed here being that the delocalised system requires more energy to break than the alternative triene would and that this is the reason for a less exothermic overall enthalpy change.
- (b) In part (ii) answers such as $<55^{\circ}\text{C}$ or $>50^{\circ}\text{C}$ cannot be credited as how far 'below' or 'above' is not clear. A reference to 'concentrated' was needed at least once when referring to the need for both nitric and sulfuric acids.
- (c) There was some confusion about the role of the $-\text{NH}_2$ side chain in ring activation with some responses referring to the electron-withdrawing effect enabling better nucleophilic attack.
- (d) The calculation in (i) proved to be the easiest on the paper, although candidates must remember to establish the link between empirical formula and molecular formula by referring to the relative molecular mass rather than just stopping having calculated the empirical formula. In part (ii) the correct structure was frequently seen but many candidates failed to spot the clue in the stem where there was a reference to the 'five protons on the benzene ring' – indicating that there is only a single side chain.

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Paper 9791/04

Practical

Key Messages

Greater familiarity with making observations would help candidates to focus on the key points in their observations rather than noting a great deal that is not relevant. In general candidates could also improve on the general way in which their results are recorded. This applies to quantitative analysis questions in terms of affording each recorded value a useful description and an appropriate unit. In qualitative analysis questions it points to using the boxes provided as a guide to where observations and deductions are needed. In many cases failure to do these did not cost candidates marks but an attention to layout does make it much easier for candidates to look back at their results in order to access values or to draw useful conclusions.

General Comment

As with last year's paper, although there were again some really excellent performances, many candidates found aspects of the paper demanding and there is perhaps still need for more practice especially in terms of the qualitative chemistry part.

In relation to the conduct of the exam, it should be stressed how important it is that Centres follow closely the requests made in the Confidential Instructions under the heading 'Responsibilities of the Supervisor during the Examination'. In particular, it is required that a set of Supervisor results be submitted for each laboratory used in a session, making it clear where more than one laboratory is used, which set of supervisor's results apply.

Comments about specific questions

Question 1

Almost every candidate followed the instructions carefully and carried out this opening experiment well, so was able to obtain values that were in good agreement with the accepted correct value.

- (a) Recordings of the mass and of the values associated with the titration were done competently but although it did not cost them any marks a large number of candidates could have shown these results more clearly and certainly have labelled the values with much greater detail. Recording of the readings from the burette very rarely failed to be to the nearest 0.05 cm^3 which was very pleasing.
- (b) Again virtually every candidate selected titres within 0.20 cm^3 and worked out an appropriate average.
- (c) (i) This proved a relatively straightforward calculation and virtually every candidate was able to work out the amount of acid that corresponded to their calculated volume of **FA 2**.
- (ii) Again this was relatively straightforward although some candidates did forget that only 25.00 cm^3 of the total volume of 250.0 cm^3 had been sampled in each titration and so gave the same answer as they had to part (i).
- (iii) This proved problematic for a number of candidates who although they started by substituting the correct values into the equation, subsequently made errors in working through the stages of the calculation.

Question 2

- (a) As in the opening question it was very pleasing to see the majority of candidates carry out this experiment carefully and all but a tiny minority then gained both of the marks for agreement with the Supervisor value. Labelling of the recorded pieces of data was done more carefully than in **Question 1** with only a very few omitting units.
- (b)(i) This was very straightforward and virtually every answer merited the mark. On only a few scripts was the sign given incorrectly. This was pleasing as the temptation for such an exothermic experiment might have been to ignore the given definition of ΔT and to have gone for the negative sign.
- (ii) This proved the most challenging part of the paper. It was hoped that having been given the expression in **1(c)(iii)**, candidates would have been pointed towards expressions that involved m and $M - m$ where m is the mass to be determined and M is the total mass. For many this was the case but they then equated the sum of the temperature changes from the sodium hydrogencarbonate and the sodium carbonate to be equal to the answer to **(b)(i)** rather than the change in temperature that they had recorded in **(a)**. Some other candidates tackled the question in terms of relative quantities of the two salts and did so successfully. It was notable from the number of incorrect answers that few had gone back through their results with the proposed masses to check if they did indeed produce the temperature rise in **(a)**. The final part involving converting the mass of sodium hydrogencarbonate into a percentage was awarded to virtually every candidate.
- (c) This was fairly well answered. The only error that featured a great deal was to forget to double the value quoted for the uncertainty in each mass in **(i)** when calculating the percentage error in **(ii)**.
- (d) It was relatively rare to award both marks for this question. Following on from the previous part, most candidates focused on the increase in mass and the resulting reduction in its percentage error. Few then went on to gain a second mark, by commenting that the temperature would remain approximately the same.

Question 3

- (a) This first part proved to be experimentally quite challenging. Although a large number of candidates were successful here, some approached this in a rather haphazard fashion with observations recorded all over the table provided. It was also notable that some proceeded to carry out their own experiments and recorded, for example, observations for adding acids to all three solids rather than simple the effect of heat on the samples. It is important for reasons of safety that candidates do not deviate from the instructions given and only perform their own tests when instructed to do so, for example in **(b)(ii)**, or when identifying gases given off. When it came to identifying the gases given off many got oxygen from **FA 7** and carbon dioxide from **FA 6** but it was rare indeed to see a candidate identify HCl from **FA 5**. Unsurprisingly a candidate's ability to identify each unknown correlated with how well the experiments in **(a)** had been carried out.
- (b)(i) Overall this was well answered with candidates recording a white precipitate being formed in each test.
- (ii) Again this was well answered. A number of candidates either did not add sufficient hydrochloric acid to the sample of barium sulfite or did not agitate the test-tube sufficiently to see the solid dissolve, while others made the error of selecting sulfuric acid. The choice of aqueous ammonia was made by nearly all the candidates who went on to observe the white precipitate dissolve indicating the presence of chloride ions.