

CHEMISTRY

Paper 9791/01
Part A Multiple Choice

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

General Comments

Knowledge of the Organic part of the syllabus, **Sections A3.1 to A3.5 (Questions 18 to 30)**, was good but candidates were less confident with the Analysis part of the syllabus, **Sections A4.1 to A4.5 (Questions 32 to 40)**.

The eight easiest questions were **1, 3, 8, 18, 19, 23, 30** and **31**. These were non-calculation items usually requiring one or two pieces of factual knowledge to get to the answer.

The seven most difficult questions were **4, 5, 11, 13, 20, 33** and **35**.

Comments on specific questions

Question 4

Candidates had to deduce that the anion was NO_2^- , but many opted for distractors **C** and **D**, thinking it was NO_3^- .

Question 5

Half of the candidates did not appreciate that O₂ and Xe had both lost an electron.

Question 11

Candidates had to realise that the products were CO₂, NO₂ and H₂O, and then balance the equation. The question required oxidation numbers to be used in an unfamiliar way.

Question 13

It was expected that candidates would initially eliminate options **A** and **C**. Many candidates then settled on option **D**, not appreciating that sodium oxide would have a higher melting point than sodium carbonate.

Question 20

A large majority of candidates realised that there were nine tertiary carbons present, but a significant number thought that only four chiral carbons were present.

Question 33

This proved to be the most difficult question on the paper. Only a minority of candidates appreciated that chloride ions would be the only ions not in the filtrate, as excess silver nitrate was used.

Question 35

This question involved knowledge of syllabus **Section A4.2 (a)**, where candidates had to realise that heavier ions will move more slowly to the detector. A minority of candidates chose **A**, perhaps confusing mass and size of ions.

CHEMISTRY

Paper 9791/02
Part A Written

Key message

Many candidates could improve their performance in the problem-solving exercises by further scrutinising the wording of the question, in which hints about how to proceed may be found. It is also worthwhile considering the wider question; earlier parts tend to cue the candidate into the correct mind-set for tackling a problem at the end of a question.

General comments

Candidates generally coped well with the paper. One area where many candidates can improve is in the precision of definitions, many of which were rather unclear. Many questions contained parts where unfamiliar material needed to be rationalised using theory from the syllabus. Candidates did not seem to suffer from shortage of time.

Comments on specific comments

Question 1

This question was based on amount and enthalpy calculations, but went on to consider surface-area effects and acid-base chemistry.

- (a) This part was answered very well.
- (b) Despite the fact that there are three steps in this unstructured calculation, it was answered very well.
- (c) This part was answered well.
- (d) A large majority of candidates were able to take account successfully of the stoichiometry and the signs for quantities.
- (e) This part was done well.
- (f) Some candidates gave their answers with an unrealistic number of significant figures for which they were penalised.
- (g) This part was a good discriminator. Some candidates believed that the enthalpy change was affected by the particle size. Credit was given to candidates who suggested that larger lumps could not react completely due to an insoluble crust of magnesium hydroxide on the surface. Candidates only received credit for asserting that there would be no difference in temperature change if they made explicit the (unlikely) assumption that the drink is perfectly insulated.
- (h) This part was answered less well than anticipated. Some candidates clearly guessed the products and pH values.

Question 2

This question tested energy changes and simple molecular orbital diagrams, and touched on ionisation energies.

- (a) (i) Candidates struggled with this part and there were many poorly expressed and ambiguous responses.
- (ii) This part was generally answered well. Many candidates did not appreciate that it is not necessary to break all six C–H bonds to do the calculation. Some candidates made sign errors.
- (b) (i) This part was answered well, apart from some sign errors.
- (ii) This part was answered well.
- (iii) This part was generally answered well. Some candidates probably lost credit through not checking what was required in the question.
- (iv) Many candidates' answers were imprecisely expressed, using words such as 'shielding' without giving any supporting explanation. Many candidates stated that effective nuclear charge decreases down the group. This is incorrect: less nuclear attraction is experienced by the valence electron on descending the group. The two statements are not equivalent.
- (v) Many candidates were able to deduce that the lower ionisation of rubidium is tantamount to its outer electron having higher energy compared to potassium.
- (vi) This question required three conversion factors, dealing with cm, kJ and Avogadro's constant. Only the strongest candidates were able to answer it correctly.

Question 3

This question tested candidates' knowledge of the van Arkel triangle, redox equations and empirical formula.

- (a) (i) This part was answered well.
- (ii) Many candidates circled "intermediate ionic-metallic" but the point was close enough to the centre of gravity of the triangle to be considered intermediate covalent-ionic-metallic.
- (b) (i) Some candidates struggled with the electrons in the half equation.
- (ii) This part was better answered, perhaps due to using a method not requiring the combination of half equations.
- (iii) Many candidates just referred to catalysis without making any reference to enzymes.
- (c) (i) This part was answered well.
- (ii) Many candidates answered with the correct number of atoms but omitted the charge or left it as 8–.

Question 4

This question tested candidates' knowledge of general organic chemistry, especially functional group level. The second half of the question required use of information from the first half of the question. Optical isomerism was also tested.

- (a) This part was answered well.
- (b) Most candidates answered this part correctly.
- (c) Most candidates answered this part correctly, although many candidates drew bonds that did not connect atoms in the realistic sense, e.g. C–H₂N.

- (d) Most candidates answered this part correctly, although some only got one of the two required words, sometimes combining it with an incorrect second word.
- (e) All but the weaker candidates were able to see the connection with carbonyl chemistry.
- (f) This part was answered well.
- (g) This part was answered well.
- (h)(i) Weaker candidates were not able to extrapolate from the quoted Strecker synthesis to work out the starting material in this case.
 - (ii) Excessively redundant nomenclature, such as butan-1-al, was not allowed.
- (i) Pairs of molecules that were not drawn to be obviously mirror images but were in fact enantiomers were accepted. Grossly unrealistic 3D representations were not tolerated.

Question 5

This question tested candidates' knowledge of volumetric calculations and Group 17 chemistry.

- (a) This part was answered correctly by most candidates.
- (b) This is a challenging question because of the two multiplicative factors that must be taken into account – the factor 100 on dilution and the factor 10 from the aliquot. Many candidates were, nevertheless, able to answer this part successfully.
- (c)(i) Most candidates thought that the product was sodium sulfate rather than sodium hydrogensulfate.
 - (ii) This part was answered successfully by most candidates.
 - (iii) Some candidates incorrectly stated that the oxidising agent is sulfur, which was not credited.
- (d)(i) This part was answered poorly, with many specious arguments being made with reference to electronegativity, electron density and ionic radii.
 - (ii) Many candidates stated that the acidic strength increased down the group because there was greater dissociation of hydrogen ions.
 - (iii) There were many weak responses relating to the bond strength of the halogen.

Question 6

This question tested candidates' knowledge of analysis and involved identification of a mystery molecule.

- (a) Most candidates answered this part successfully.
- (b) Most candidates were able to spot the scope for positional isomerism with the compound.
- (c) This answer was answered well.
- (d) This answer was answered well.
- (e)(i) Only stronger candidates were able to correctly give the wavenumber values.
 - (ii) There were many unusual descriptions given in response to this question. The standard term is "broad".
- (f) Stronger candidates were able to see the necessity for a three-membered ring.

Question 7

This question consisted of two very different practical planning exercises. The first involved identifying organic unknowns and the second involved an organic synthesis, separation and purification. The first was expected to be straightforward for candidates, based on an exercise they would have probably done before, and the second one was more challenging.

- (a) Many candidates' responses would have benefited from being more clearly organised. Credit was given for proper identification of reagents, e.g. acidified sodium dichromate(VI). The most difficult part was to differentiate between the two alcohols. Where the chosen method involved taking advantage of the different oxidation products, then some consideration should have been given to the means of separating the product. For example, refluxing with acidified sodium chromate and investigating the pH at the end of the reaction is bound to reveal an acidic pH on account of the excess acid used for the reaction.

Some strong candidates were able to make elegant use of Lucas reagent to identify and discriminate between the alcohols with a single reaction. Extra credit was awarded for the economy of this approach.

- (b) This is a challenging question in which only the strongest candidates really excelled. However, credit was given for sensible steps, even as part of an over all unrealistic approach. Good candidates realised that the information in the question about hexane's properties was hinting at its suitability for recrystallisation of the product.

Most candidates used a suitable reducing agent in a suitable solvent and warmed the mixture. More able candidates then hydrolysed the product. Most realised that a good way to test the purity of the product was to determine its melting point. More able candidates realised that water was an ideal liquid with which to wash the product. The most difficult part was separating the product from the reaction mixture, which depended on whether ether or ethanol was chosen as the solvent for the reducing agent.

CHEMISTRY

Paper 9791/03
Part B Written

Key Message

There is a tendency for the stronger candidates to simply write down everything they know about a topic, when more careful attention to the specific requirements of the question would yield better results, and also reduce the need for the use of extra answer booklets.

General Comments

As in previous years, the recall of fundamental principles was good amongst most candidates although there were some weaknesses noted in the application of fundamental ideas to unfamiliar contexts, a key principle of the Pre-U.

Comments on Specific Questions

Question 1

This was intended as a relatively straightforward start to the paper, based on **section B2.3** of the syllabus.

- (a) Parts (i) and (ii) were generally answered well, although the clarity of explanation in (ii) of the longer 'bond' length between the layers was somewhat variable. Note should always be taken of the amount of credit available, as the key to (ii) was to specifically identify the bonding between the atoms in each layer as covalent with the bonding between layers being van der Waals; it is not appropriate in this context to refer to these forces as 'intermolecular'. Full credit in this part was available to candidates who went on to indicate that the greater strength of the covalent bonds is responsible for the smaller separation.

In (iii) simply referring to the strength of the covalent bonds in diamond is not sufficient to justify the hardness, as the covalent bonds in graphite are of a similar strength; reference must also be made to the tetrahedral arrangement of the strong bonds around each carbon atom. A more general comment relating to this part and others is the point that, when a comparison is required, both sides of the argument must be addressed rather than simply making one statement and leaving the opposite argument implied. In this case a discussion of the conductivity of diamond and graphite requires both the presence of delocalised electrons in graphite **and** the absence of any mobile charge carriers in diamond to be identified.

- (b) Many candidates were only awarded minimum credit here because their answers were not specific enough. A generic statement about conductivity increasing down the group was not sufficient in this case as the question asked for reference to be made to "electrical conductivity of the element". Similarly, for the oxides, specific identification of the covalent molecular nature of CO₂, the giant covalent nature of SiO₂ (and GeO₂) and the (increasingly) ionic character of the oxides of tin and lead were all necessary.
- (c) Once again, specific data requires specific responses and many candidates only answered half the question.

Question 2

There were some weaknesses highlighted by this question, notably with unfamiliar calculations, despite provided data and contexts, and basic electrochemical cell conventions.

- (a) Parts (i) and (ii) were generally well answered, although a number of candidates were unable to offer a correct ionic equation or K_{sp} expression. In (iii), some candidates lost credit for not showing their working. Despite having given an incorrect final answer, credit could have been awarded for earlier working if it had been clearly shown.

In (iii) very few candidates were able to score more than minimal credit mostly because they did not allow for the various volume conversions necessary. Candidates would be well-advised to plan their answers to such questions using a 'flowchart' type approach.

- (b) Cell diagrams rely on the correct application of several conventions. Many candidates lost credit for not observing such conventions when constructing the right-hand half-cell in this diagram. The higher oxidation state (Ag^+) must be next to the salt bridge (||), a solid line must separate the two species as they are in different states, and the state symbols must be included.

In (iii) a number of candidates assumed that $[Ag^+]^2 = 1.8 \times 10^{-10}$, i.e. the K_{sp} given in the question, despite the fact that the chloride ion concentration was given in the previous paragraph.

Question 3

The example of homogeneous catalysis used in (b) was expected to be familiar as it is so commonly used to illustrate this principle, but the question should have been accessible, even to those who were not familiar with it, as an application of ideas in an unfamiliar context. The reference to chymotrypsin in (c) almost certainly represented the need to apply basic principles in an unfamiliar context.

- (a) This was generally well answered although some weaker candidates made some unexpected suggestions.

- (b) Parts (i) to (v) were well answered, but part (vi) proved more challenging, perhaps indicating that the context was less familiar than expected. As the overall equation was given in the stem it was expected that separate equations would be constructed for the interactions between $Fe^{2+}/S_2O_8^{2-}$ and Fe^{3+}/I^- and then the point made that they could occur in either order to justify the use of either Fe^{2+} or Fe^{3+} as the catalyst.

- (c) A surprising number of candidates were insufficiently specific in part (ii) and offered the answer that the curly arrow represents the "movement of electrons" rather than specifically identifying that an arrow of this type shows the movement of a pair of electrons.

Given that the diagram shows the protonation of COO^- (in asp102) is the first stage, candidates needed to recognise, in (iii), firstly that a low pH corresponds to a high $[H^+]$, and then that this would result in the COO^- being protonated and hence unavailable for this first stage.

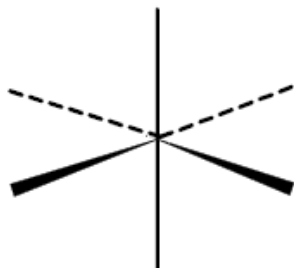
In (iv) many candidates were unable to answer the second part of the question, for which it was necessary to recognise that the use of excess alkali would make $[OH^-]$ effectively constant. In (v) many did not recognise that the data on the vertical axis was already \ln [chymotrypsin], and used, for example, $\ln 2.3 \times 10^{-5}$ in their calculations.

Question 4

This proved to be a relatively straightforward question for most candidates although credit was again lost through a lack of specific application of ideas to the requirements of some parts.

- (a) There was a need here to consider the processes of both bond-breaking and bond-forming, and to recognise that, as well as the bonds that are broken being identical in each case, the bonds being formed were C-N in both cases. The alternative answer that similar enthalpies of hydration as both ions formed are 2+ was not suggested by any candidates.

- (b) In this part many candidates overlooked the fact that there are effectively two questions here with the result that most responses focused on the difference in the values, without making an initial comment about the values themselves.
- (c)(d) These parts were generally well answered although the quality of drawing of 3-D representations was variable. Candidates are advised to stick to the conventional use of 'wedge and hash' bonds when drawing 3-D representations so that an octahedral structure should appear as



Question 5

There was evidence here that some candidates could have spent more time on the learning of organic inter-conversions, and/or that their application in unfamiliar contexts caused problems.

- (a) Very few candidates were able to name all four functional groups present. Despite the instruction to name fully all the groups, relatively few candidates included 'primary' and 'secondary' when identifying alcohol groups, and the secondary/substituted amide group was not well recognised, with many suggestions involving ketone and amine groups.
- (b) In (i) most candidates recognised where the hydrolysis would occur, but a large proportion thought that an acid and an alcohol would result. Most of those who recognised that an amine would be produced failed to protonate it in their suggested products. In (ii) the acid group was usually correctly shown reacting with sodium, but the alcohol groups were less frequently shown.
- (c) The chiral carbon was identified by most candidates in (i) but a lack of clarity was again the downfall of many in explaining the meaning of 'R' in part (ii). The key to success is not simply to state that the groups are arranged in order of priority, but to make clear what that order is.
- (d) The calculation in (i) was familiar to most and well answered, but there were many confused responses to (ii).
- (e) The weakest part here was (ii) where, as with the sodium in part (b)(ii) many candidates omitted to show reaction with all relevant groups, and some went too far and included the NH group.

Question 6

Now that the style of this paper is becoming established it was hoped that candidates would be better equipped to tackle the identification and explanation question in (d) but many answers were poorly organised and many ignored the instruction to "refer to the splitting patterns and integration of **all** the peaks".

- (a)-(c) These parts were well answered but few candidates were able to 'translate' the clues from the given name to answer (c). Most candidates seemed to believe that the '2' referred to the position on the ring, despite there being only one side-chain, and retained this number in their own attempt at an answer.
- (d) The key to success here is to adopt an organised approach with a full discussion of each signal in turn. Some candidates confused the origins of the splitting and integration data and needed to be clearer when referring to these ideas.
- (e) This part was generally well answered although candidates needed to be aware, in part (ii), of the requirement to justify their conclusion and, in part (iii), to include a positive charge whenever they identify a particle responsible for a peak in a mass spectrum.

- (f) Most candidates gained half of the available credit in both sections. In part (i) the structure was often given without the confirmation and in (ii) most comparisons pointed out the difference but omitted to mention the similarity.

CHEMISTRY

Paper 9791/04

Practical

Key Messages

Candidates should read through all the practical instructions before starting the experiment, and where possible draw up a table for their results. By doing this the candidate is forced to think carefully about what the experiment is aiming to achieve and is therefore less likely to make errors in the analysis section that follows.

Candidates should ensure that they are familiar with the material contained in the *Data Booklet*.

General Comment

Although there were some excellent performances in this paper, it would also be true to say that overall candidates found this year's exam more demanding than those of previous years. As such it revealed areas that should be considered when preparing future candidates. From many of the responses to **Question 3(a)**, it appeared that some candidates were not using the information provided in the *Data Booklet* about qualitative tests.

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's results be submitted for each laboratory used in a session. It is also important to stress strongly that the Question Paper must not be opened by Centres in advance of the examination date.

Comments on specific questions

Question 1

- (a) Most candidates carried out the experimental part of this first task very competently and obtained results which were comparable with those of their Supervisor. A significant number, however, omitted to give the mass of the residue and the mass of water loss, which lost them credit. This could have been avoided if the candidates had read all the instructions and drawn up a results table before they started any practical work.
- (b) A number of candidates found this calculation relatively challenging. Although nearly all started their analysis by calculating the amount of water that had been lost, methods after this varied. Some took the easiest route of working out the relative formula mass of either the hydrated or the anhydrous salt, although here a number muddled these two readings from their results table. Others chose to work out the mass of chloride in the residue and hence the mass of metal present. For the final step a number of candidates, having correctly determined the relative atomic mass, then forgot to state to which metal this corresponded.
- (c) Overall this was well answered with a range of sensible suggestions that were well reasoned.

Question 2

- (a) This was a relatively demanding practical with a titration that candidates may not have come across previously. Despite this, the overall standard of practical work was good, with titration results that varied little between the separate runs and were in good agreement with those of the Supervisor. The results were well presented and only a few candidates lost any of the credit available for the first part of the experiment. When this did occur it was mostly where the candidate did not give the values to the nearest 0.05 cm^3 .
- (b) This was well answered with virtually every candidate scoring full credit.
- (c) This calculation started well but then many candidates simply quoted the same answer again for part (ii), forgetting that they had only sampled 25.00 cm^3 from the 250 cm^3 volumetric flask. This also led to a very small answer for the final percentage, something which should have alerted candidates to the fact that an error had occurred. Nearly all candidates worked to an appropriate number of significant figures throughout the calculation.
- (d) In the first part, few candidates remembered to double the individual reading error in order to judge the error in each single titre. In the second part, some approached the answer by the easiest route of simply repeating the percentage calculation using the smallest possible value for their volume recorded in (b). Others, however, muddled the percentage error with the percentage of chloride and tried to get to the answer by manipulating these two values. Overall this part was not well answered.

Question 3

- (a) This proved to be one of the more challenging sections of the paper. Despite the provision of the analysis notes in the *Data Booklet*, many candidates quoted results for their tests with sodium hydroxide and aqueous ammonia that either contradicted each other or were at odds with those that are listed in the *Data Booklet*. Overall, the clarity with which these tests and their results were recorded was very poor. This was particularly true of the test for ammonia where, in many cases, it was very difficult to judge the candidates had tested the gas given off or the solution. When it came to identifying the cations, it was H^+ that was noted the least often, with very few candidates carrying out any tests to identify acidity. It was also noteworthy that a significant number of candidates carried out tests to identify anions.
- (b)(i) The answers to this were often very confused. Some candidates suggested adding barium chloride or lead nitrate but then lost credit by either failing to state what acid they would use or selecting an inappropriate acid such as sulfuric, in the case of barium chloride, or hydrochloric, in the case of lead nitrate. Of those who looked to identify SO_2 being formed as a possible route to identify the anion, many did not realise that this would be a gas and so suggested adding acidified dichromate to the solution, which they then did in part (ii).
- (ii) Following on from the answers in (i), there were a range of different tests quoted in this part. In the main, however, the results were described correctly and led to the correct identification of the sulfate anion.
- (c)(i) The first part was well answered with nearly all candidates noting the correct colour. Although it was not necessary for the credit, candidates should note that it was the **solution** that changed colour, as many candidates simply wrote 'colour changes to pale yellow' which is not as complete an answer as it could be. In the second step, the candidates needed to note that a precipitate was formed, and consequently some lost credit for simply saying 'it turned red-brown'. Few candidates were awarded full credit in this part as, although many noted the effervescence, few tested the gas to show it was oxygen.
- (ii) Although many candidates correctly noted that $\text{Fe}^{3+}(\text{aq})$ had been formed, a significant number did not then go on to explain the origin of the effervescence.