

CHEMISTRY

Paper 9791/01
Part A Multiple Choice

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

General Comments

The paper consisted of 40 questions which involved choosing a correct answer from a choice of four.

Comments on Specific questions.

The six questions found most straightforward by candidates were **10**, **16**, **17** and **26**. These were non-calculation items usually needing only one or two pieces of factual recall to get to the answer.

Average candidates or better coped successfully with the three calculation items **15**, **32** and **33**.

The eight most challenging questions were **9**, **12**, **13**, **20**, **21**, **25**, **31** and **36**.

In **9**, a significant number of candidates thought the atomisation of chlorine was as given in the question and so gave an answer other than **A**.

In **12** a significant number of candidates did not realise sulfur dioxide would react with the alkali potassium hydroxide and so flask P should be omitted.

From the data given in **13** many candidates were unable to deduce the reaction needed was between I_3^- ions and $S_2O_3^{2-}$ ions.

In **20** a significant number of candidates did not realise there were two cyclic structural isomers without a C=C, with a minority of candidates opting for the correct key, **D**.

Question 21 required candidates to work out the structural formula of the named hydrocarbon and then deduce the presence of a chiral carbon atom and the absence of geometrical isomers.

Initially in **25** compound **X** had to be deduced as $HO_2CCH_2C(OH)CH_3CH_2CO_2H$. Candidates then had to realise **X** was symmetrical with no chiral carbon atom and only four different carbon atom environments.

The key fact to **31** was knowing lead chloride was insoluble as indicated in 'Reactions of anions' in the Qualitative Analysis Notes. A significant proportion of candidates gave **A** or **B** believing calcium or magnesium chlorides were insoluble.

Question 36 proved the most difficult of all. A significant proportion of candidates gave **B** thinking the number of electrons rather than the electron-electron interaction was the reason.

CHEMISTRY

Paper 9791/02

Part A Written

Key messages

Candidates are reminded of the need for accuracy in the drawing of organic structures, particularly 3D representations. Candidates were penalised for connectivity errors, e.g. $\text{OHCH}_2\text{CH}_2\text{OH}$, and dangling bonds where an H should be written. In 3D representations, a wavy line is not an acceptable alternative to a hashed bond (as a wavy line denotes unknown stereochemistry). This is consistent with IUPAC recommendations: <http://pac.iupac.org/publications/pac/pdf/2006/pdf/7810x1897.pdf>.

Centres are reminded that standard pressure is 1 bar, not 1 atm, and that “standard conditions” does not specify the temperature.

Many candidates lost marks from evidently not reading the question properly, *i.e.* not providing what the question asked for.

General comments

Candidates coped well with the unfamiliar contexts presented to them in the paper. Those who clearly laid out the working to calculations benefited from error-carried-forward marks if they made a mistake. Similarly, partial credit was also awarded in descriptive questions when correct relevant chemistry was expressed even if a mistake had been made elsewhere.

More challenging questions, where there is little guidance to the candidate, are often solved by using clues in the question. When a question is broken into several parts, the method for one part often follows on from the result obtained in the previous part. The skill of using the information provided in the question was particularly important in the practical **Question 6**.

Question 1

- (a) (i) Since the question specifically called for a sign, candidates were penalised for not including the plus sign with their answer. Similarly there was no tolerance with the 1 d.p. that was required. Generally the question was well done.
- (ii) This part was answered correctly by virtually all candidates.
- (b) (i) Candidates needed to state explicitly that the combustion was either complete or in excess oxygen. The definition should begin “the enthalpy change when...”. “The energy released when...” was penalised.
- (ii) Many candidates struggled with this enthalpy question. The question could be answered using the enthalpy change of reaction calculated in the first part or instead using the enthalpy of formation data. Any valid method that gave the correct answer received full marks. Many candidates gained partial credit.
- (iii) Candidates were given credit for alternative chemically valid answers that were correctly expressed.
- (c) (i) This part was answered correctly by virtually all candidates.
- (ii) Candidates needed to make clear that their argument was about ions. Candidates should beware of using ‘it’, etc., in contexts where it may not be clear what they are referring to.

- (iii) Most candidates were correctly guided by the broken circle of the diagram to completing it using the lime obtained from decomposing the limestone.

Question 2

- (a) Candidates need to ensure that they specify 'element'.
- (b) (i),(ii) Both parts were answered well.
- (c) (i) Many definitions were loose or incomplete. Quite a common error was to refer to standard conditions.
- (ii) Candidates found this calculation challenging though many were awarded partial credit.
- (d) (i) A common error was to put 'tetrahedral'. While a diagram was not requested, credit was given to a correct dot-cross diagram.
- (ii) A common error was to put 'methane'.
- (e) (i) Many candidates did not label their hydrogen-bond and did not indicate bond angles. A common error was to draw the hydrogen-bond from a hydrogen on water rather than the hydronium ion.
- (ii) This part was marked generously: any structure with three hydrogen-bonds between the ion and the macrocycle gained credit.

Question 3

- (a) Most candidates answered part (i) correctly. Those candidates who calculated the coordinates from the electronegativity values nearly all plotted their graphs correctly; those candidates who drew lines parallel to the sides of the triangle were sometimes not accurate enough in doing so. Parts (ii) and (iii) were answered well.
- (b) A common error in (i) was to draw a covalent bond between a sulfur atom and the iron ion. Part (ii) was answered well.
- (c) In part (i) some reference to 'whole numbers' was required. Part (ii) was answered well by most candidates. Only the stronger candidates were able to work out parts (iii) and (iv).

Question 4

- (a) (i) The majority of candidates had H₂ as a product.
- (ii) 'Substitution' or 'radical substitution' was the intended answer. Reference to nucleophiles or electrophiles was penalised.
- (iii) In 3D representations, a wavy line is not an acceptable alternative to a hashed bond (as a wavy line denotes unknown stereochemistry). This is consistent with IUPAC recommendations.
- (iv) This part was answered well.
- (b) This part was answered well. 'Hydroxide' alone was not sufficient to score the reagent mark.
- (c) Unless a skeletal formula was given, the Hs needed to be included to score the mark.
- (d) 'Aldehyde' was the intended answer in part (i); just 'carbonyl' was not enough. Parts (ii) and (iii) were answered well. In part (iv) there were some careless mistakes in calculating molar masses. Most candidates correctly worked out the structures in (v) though only stronger candidates solved the structure for **G** in part (vi).
- (e) (i) Candidates were required to include the double bonds but not to show the correct geometry.
- (ii) Candidates were required to include the triple bond but not to show the correct geometry.

Question 5

- (a) (i) A common error was for the line showing the repeat unit to pass directly through atoms rather than cutting bonds.
- (ii) This part was answered well.
- (iii) Most candidates answered this part correctly.
- (iv) Candidates needed to be specific that hydrogen-bonds were being formed between the polymer and the water. Just to indicate that polymer and solvent were both polar was insufficient.
- (v) Only stronger candidates were able to get both structures correct.
- (vi) The idea of the question was to realise that the functional group level of the carbon atoms does not change on polymerisation and therefore that the monomer with both atoms at FGL1 was the one that produced the PEG. This part discriminated well.
- (b) (i) This part was answered quite well. Candidates must take care not to make errors in connectivity when writing structures, e.g. $\text{OHCH}_2\text{CH}_2\text{OH}$.
- (ii) Only the more able were able to use the clue that all five silicon atoms were in the same environment to infer that the molecule must be cyclic.

Question 6

- (a) (i) Most candidates answered this part correctly.
- (ii) A common error was the omission of state symbols.
- (iii) Weaker candidates thought the precipitate was silver or invoked effervescence.
- (b) (i) 'Precipitate' had to be specified to gain credit for this part.
- (ii) This question discriminated well between candidates. A common error was to cite a large energy change.
- (c) (i) Only stronger candidates got the correct stoichiometry. Incorrect stoichiometry was not subsequently penalised in later question parts.
- (ii) This part was answered well.
- (iii) The insolubility of AgI in ammonia is the crucial point that had to be specified.
- (d) (i) With 0.05 molar silver nitrate provided and the 1:2 stoichiometry of the silver : cyanide reaction, then 0.1 molar cyanide will be convenient, as equal volumes of the two solutions should react. Given that about 0.01 mol of cyanide is provided, the logical thing is to prepare a 0.1 dm^3 solution of it. Hence the intended method was to prepare a standard solution of the cyanide sample in a 100 cm^3 volumetric flask and to pipette 10 cm^3 aliquots for each titration. A 250 cm^3 volumetric flask was acceptable if using a 1:1 stoichiometry. Credit was given to specifying good laboratory practice, e.g. transferring with washings, weighing by difference, using deionised/distilled water, proper mixing, etc.
- (ii) Candidates were not penalised for errors made earlier in the question. Some candidates introduced a significant error by taking the amount of cyanide to be 0.01 mol. Given the emphasis on precision in titrations this error was penalised.

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Paper 9791/03

Part B Written

Key Messages

Success in this paper, as always, requires careful application of learning to the context of the question especially when the context established by the question is unfamiliar. Clarity is crucial in written responses as exemplified by the large number of candidates referring to 'the temperature at which...' in **Question 2(b)(iv)** rather than 'the temperature above which...'. It is also vital that working is shown clearly, in a logical sequence, in calculations as credit can therefore be given for valid steps when the final answer is incorrect.

General comments

Centres are encouraged to make good use of the past papers so that candidates become familiar with the level of demand and the style of question.

The best responses were seen in calculations, while the best written responses were distinguished by their clarity notably in **1(b)(ii)** and **(iv)**, **3(c)(iii)**, **5(b)(iii)** and **5(d)(ii)**.

Comments on specific questions

Question 1

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

- (a) A significant number of candidates chose to write the configuration of Mn as $4s^2 3d^5$. While this was allowed for credit to be awarded, it should be discouraged as it leads to difficulties of perception when candidates then try to explain patterns of ionisation energies, as it can give them the impression that the 3d electrons are the 'outer' electrons.
- (b) In part (i) the definition can either be approached in terms of the energy needed to remove an electron from **each atom in a mole** or in terms of the energy needed to remove a mole of electrons from a **mole of atoms**. Many candidates confused the two approaches with phrases such as 'the energy needed to remove a mole of electrons from an atom...'. Part (ii) was an example of a situation where clarity of explanation was key and also it was clear that many candidates were unable to offer a clear response due to their perception of the configuration as being '4s 3d', which made it difficult for them to refer to the addition of electrons to an inner subshell leading to an increase in shielding along with the increase in nuclear charge. Part (iii) was well answered. In part (iv) there were many good answers but some candidates referred simply to 'the stability' of a full or half-full subshell, which does not actually constitute an explanation.
- (c) Part (i) was a good example of a situation where candidates should be aware of the importance of looking at the credit allocation, as three distinct ideas had to be offered for full credit to be awarded. There were relatively few correct answers given for part (ii); many candidates offered cations or neutral species rather than the anion asked for.
- (d) This was generally answered well. A small number of candidates did not apply their knowledge of cobalt being hexa-coordinate in such complexes and so struggled with the diagrams in part (v).

Question 2

This question tested the application of ideas and calculations related to free energy, entropy and K_p .

- (a) This section was well answered with part (iii) being a simple example of this type of calculation as there were no 'multiples'.
- (b) Most candidates remembered half of the definition in (i) correctly but it must be remembered that the idea that starting and final conditions need to be the same is a key part of the overall definition. Part (ii) was well answered. In part (iii) a significant number of candidates used the wrong data, possibly assuming that the question was about the formation of CaO rather than, as described, about the conversion of limestone to quicklime. A number of candidates got confused between values in 'J' and in 'kJ'. The clarity of explanation of the significance of the calculated temperature in (iv) was sometimes inadequate.
- (c) A number of candidates did not remember the format for the expression in (i) and a large number incorrectly included square brackets. In the calculation in (ii) the commonest errors involved using the incorrect temperature and the wrong units.

Question 3

This question covered some recall and application of ideas related to electrochemical cells, an analysis calculation and the application of Le Chatelier's principle.

- (a) Credit was lost in part (i) due to candidates omitting to indicate the concentrations of solutions required and not appreciating the need for a mixture of dichromate, Cr^{3+} , and H^+ at E. The equations in parts (ii) and (iii) were generally well done, although a number of candidates were unable to balance the chromium and wrote an equation with a dichromate ion (two chromiums) on one side and only a single Cr^{3+} ion on the other. Candidates would be well advised to remember the basic check of both charges and numbers of species when writing such equations.
- (b) In part (i) many candidates made the mistake of using the molar volume at 298 K, despite the conditions given being 303 K such that the use of $pV = nRT$ was required. Parts (ii) and (iii) were well done and ecf was, of course, allowed from the frequent incorrect answers to (i).
- (c) Parts (i) and (ii) were well answered but there was significant confusion demonstrated in part (iii), with many references to nitrate ions reacting with H^+ ions to form HNO_3 , sometimes followed by the suggestion that the solution therefore became more acidic due to the formation of the nitric acid. Candidates must take careful heed of questions phrases such as 'state and explain' and also to lists of references required in the answer – here requiring the ideas of equilibrium position, K_c and pH to be addressed.

Question 4

A question based on organic analysis and isomerism.

- (a) This was generally well answered, although some candidates failed to mention the 'non-superimposable' nature of the mirror images in the first definition.
- (b) This was generally well answered with this approach to NMR being more straightforward than in some previous papers.
- (c) Also generally well done, although the equation for reaction with carbonate caused some unexpected difficulties and, in part (iv) many candidates confused nucleophilic addition with substitution and incorrectly referred to the planar nature of 'the carbocation intermediate' rather than to the planar nature of the carbonyl.

Question 5

This was a typical organic chemistry question aiming to test familiar recall chemistry, although, again, the clarity of explanations was key.

- (a) Most candidates were able to remember the necessary reagents and conditions although the use of Sn/HCl was not well-remembered in part (ii).
- (b) In part (i) the majority of candidates were able to describe the decolouration of bromine, (and often also correctly mentioned that it would then remain coloured when in excess), but very few mentioned the characteristic white precipitate that would be seen. Similarly, few were able to produce the correct, balanced equation in part (ii). In part (iii) a clear explanation was needed, but many candidates used phrases such as 'more susceptible to attack by the electrophile' rather than actually explaining 'why' by referring either to the greater attraction between ring and electrophile or to the greater polarising power of the ring on the bromine.
- (c) This was generally well answered.
- (d) A number of candidates were unable to produce the correct equation, and the order of basicities was also not well known.

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Paper 9791/04
Practical

Key message

Candidates are encouraged to think very carefully about the chemistry that lies behind any practical analysis.

General Comment

This year's paper saw many excellent performances. Candidates were able to carry out the experiments carefully as could be judged by the overall excellent agreement between the candidates' results and those of their Supervisor. In using the practical data they had gathered, the calculations in **Questions 1** and **2** were well handled and the deductions in **Question 3** were largely secure apart from **3(b)(iii)**. The most challenging **Question 2(e)** revealed however the need for all candidates to think very carefully about what lies behind any practical analysis.

Comments about specific questions

Question 1

- (a) This was extremely well answered with nearly all the candidates following the instructions carefully. In particular, all candidates followed the final instruction and recorded the initial mass of the mixture and the mass of water lost but some went further and recorded the mass of the residue after heating. Although this in itself was not a problem it did in some cases lead to confusion in **(b)(ii)** where some candidates then used the wrong mass in their calculations. The agreement between the candidates' results and those of the Supervisor was excellent.
- (b)(i) This was well answered and only a few candidates quoted here the mass of solid remaining.
- (ii) Overall the majority of candidates scored the marks for this section but often they set about the calculation in a rather convoluted route. Some worked out the moles of water from the mass in **(i)**, then used this to calculate the moles and subsequently the mass of BaCl_2 . They then combined these numbers to give the mass of the hydrate in **FA 1**. Others, a significant minority, approached the calculation as a ratio of amounts and so calculated the amount of barium chloride dihydrate that would have been present were **FA 1** to have been 100% pure. They then compared this to the amount of the hydrated salt that they knew was present as a result of measuring the mass of water lost. Although there is nothing mathematically wrong with this approach it is better suited to percentage yields as it is conceptually unsatisfactory and can be confusing to have to assume that **FA 1** is the pure salt.
- (c) Few candidates here noted the effervescence of the sample. Without this it was then understandable that a candidate would not be put on the path to identifying the gas as carbon dioxide and so many scripts contained details of different gas tests such as using litmus papers, or acidified dichromate solution. Among these there were of course many who did get a positive test with limewater and so then correctly identified the presence of the carbonate ion.
- (d) Many of the candidates quickly identified the need for the salt to be thermally stable and furthermore were able to explain exactly why this needed to be the case.

Question 2

- (a) As in the first question, candidates handled the practical part of this paper very well indeed. Data were recorded clearly although it would be worth stressing here that many candidates could be

encouraged to use more conventional headings rather than just 'initial' in place of 'initial reading', or 'volume' in place of 'titre' or 'volume added'. This was not penalised in this paper but is something that could be improved. Agreement to Supervisor was not quite as good as in the opening question but nevertheless still of a high standard.

- (b) Virtually every candidate selected appropriate titres from the values they had obtained and having done so calculated a correct average which they then quoted to the appropriate number of decimal places.
- (c) Overall these calculations were well executed with most candidates able to follow the relatively simple steps to arrive at the correct answer. It is worth noting that even when the calculation is broken into these series of smaller steps, it is still good practice for a candidate to lay out their working clearly. This is, of course, particularly important when an error occur such as arriving at the wrong value for the molar mass of ammonium chloride as then it is clear to the Examiner that this has happened.
- (d) In general this was well answered and most candidates remembered to double the reading error of $\pm 0.05 \text{ cm}^3$ when working out the percentage error in their titrated volume. Some confused their apparatus and doubled the value of $\pm 0.06 \text{ cm}^3$ for the pipette. Whatever values they took forward into the calculation of the percentage error, virtually every candidate scored the second mark.
- (e) This was undoubtedly the most challenging question on the paper and really required candidates to stop and think very carefully about the way they had carried out the experiment compared to the method detailed in this part. Weaker candidates continued along the line of part (d) and discussed the number of times volumes would have to be measured. Stronger candidates did realise the problem of evaporation but often thought this was a weakness of the second method. Only a very few candidates were able to give the detailed and clear explanation that was needed here to gain both marks.

Question 3

- (a) (i) This was a relatively straightforward opening part to the qualitative question and most candidates had no problem in noting down the correct observations.
- (ii) Supported by the correct observations in (i) almost every candidate proposed plausible ions.
- (iii) A range of reagents were suggested that could rule out the presence of Pb^{2+} ions. Among these hydrochloric acid was the most common but potassium iodide was also suggested which is, of course, better given the lower solubility of lead iodide.
- (iv) For the vast majority who had carried out a useful test in (iii), identifying the ion was straightforward.
- (b) (i) This proved to be in practical terms a challenging part of the paper. Many candidates did observe that only **FA 5** gave a reaction but some, perhaps by not using clean test-tubes, saw some evidence of reaction with **FA 6**.
- (ii) This was invariably well answered though some candidates did not seem to have added sufficient acid and so reported solutions turning brown rather than colourless. Others seemed to have added much too much permanganate or else not heated sufficiently and so recorded the solution remaining faint pink. These, however, were the rare exceptions and most candidates recorded all three tests correctly.
- (iii) All but a few candidates were able to identify **FA 7** as the tertiary alcohol which had not reacted in either of the two tests. Clearly if the candidates had observed Tollens' reagent to react with both **FA 5** and **FA 6** in (i), they then were not able to distinguish them, a situation accommodated by the mark scheme. This said, however, candidates finding themselves in this position should have tried the Tollens' test again and although candidates may have done this there was no obvious evidence from the scripts.
- (iv) This was poorly answered, not as a result of candidates recalling the reactions of an aldehyde incorrectly but simply because many only answered in terms of the reaction with Tollens' reagent and failed to discuss the permanganate test at all.