

CHEMISTRY

Paper 9791/01
Multiple Choice

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

General comments

The paper consisted of 40 questions, which involved choosing the correct answer from four alternatives. Candidates seemed less confident with calculation questions.

Candidates found **Questions 13, 18, 22, 26, 27, 28, 31, 35, and 37** the most challenging.

Comments on specific questions

Question 13

Many candidates did not recognise an example of an S_N1 type reaction involving hydrolysis of a tertiary alkyl halide.

Question 18

Candidates found it challenging to determine the ratio of masses at each electrode and simplify this information.

cell X	cell Y
27 (from Al^{3+})	3×23 (from Na^+)
27	69
9	23

Question 22

Many candidates did not recognise the colours seen in such a titration; pale green (Fe^{2+}), yellow (Fe^{3+}) and purple after a large excess of MnO_4^- was added.

Question 26

A common incorrect response was **C**, which is the product on initial hydrolysis using NaOH. Addition of excess acid would then produce the aromatic acid C_6H_5COOH .

Question 27

Fewer than half of the candidates gave the correct answer. The other responses were chosen equally, suggesting candidates were not confident in this topic.

Question 28

The most common incorrect answer was **C**. Candidates did not seem to appreciate that two of the labile hydrogen atoms were in fact in the same labile hydrogen environment.

Question 31

This question was a challenge to many candidates with options **B** and **C** incorrectly chosen by large proportions of candidates.

Question 35

A large proportion of candidates incorrectly chose option **D** which gave an incorrect reason for the observation that the solution is colourless.

Question 37

A and **D** were commonly chosen incorrect options here.

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Paper 9791/02
Part A Written

Key messages

Candidates should be reminded to read the question correctly. Organised working and a logical approach helps with attempting challenging calculations. Candidates should have a secure knowledge of definitions and syllabus content and be confident in applying this to unfamiliar scenarios.

General comments

Most candidates did well on the paper and nearly all made a good attempt. There was a significant number of outstanding scripts. Others showed evidence of a lack of understanding of chemistry at this level.

Comments on specific questions

Question 1

- (a) This definition not well known. Many candidates did not mention aqueous or water or dissolving. Hydrated was not sufficient to describe the process, since crystals may also be described as hydrated.
- (b) (i) This part was done very well.
(ii) This part was well answered.
- (c) (i) Most candidates gained credit for this calculation.
(ii) The drawing of the enthalpy cycle was found difficult by many candidates and some did not attempt it. Clear and logical working was useful here; many did receive at least partial credit.
- (d) This part was answered well generally.
- (e) This part was answered to a high standard by the majority of candidates.
- (f) (i) This part was generally answered well.
(ii) Many candidates did not mention ions. The concept of charge density was often mentioned. Size however was often omitted and if included some candidates thought the ions were of similar size. Candidates should ensure that their answer makes clear what is polarised.
(iii) Most candidates stated the correct carbonate, but many did not give a correct explanation.

Question 2

- (a) (i) This question part was generally answered well, though there was some confusion over the distinction between the polarity of bonds and molecules.
(ii) Some candidates compared the elements selenium and sulfur rather than the compounds, and some compared the strength or polarity of the bonds rather than the intermolecular forces.

- (b) (i)** This part was answered quite well.
- (ii)** Common errors seen in this question were the omission of the inner shell electrons, a diagram showing covalent bonding, missing charges or the incorrect number of electrons.
- (c) (i)** This part was answered well by most candidates.
- (ii)** Most candidates realised the significance of all the products being solids.
- (iii)** Candidates often did not label the activation energy with an arrow. Some candidates gave no energy axis or labels, others gave arrows between incorrect energy levels, and quite a few used double-headed arrows.
- (iv)** Many candidates found the sign of the numerical answer difficult, but most appreciated the need to use the factor of 8 in the calculation.
- (d)** Some candidates found the conversion of units difficult.

Question 3

- (a) (i)** This part question was well answered.
- (ii)** There was some confused working by candidates and a common error was to not use the correct proportion of aluminium in the aluminium oxide. Many candidates gained full credit.
- (iii)** Candidates used a variety of methods to obtain the correct answer to this question.
- (b)** This part was answered well.
- (c) (i)** Many candidates wrote balanced equations but with a range of incorrect compounds and formulae. A common error was to give Na_2O as the product. Other equations contained correct species but were not balanced.
- (ii)** This part was answered well.

Question 4

- (a)** Some candidates found it difficult to give the correct charge which often lead to the incorrect number of electrons being shown.
- (b) (i)** This part was generally answered well, though some candidates confused atoms and bonds or gave answers that only referred to the chlorine atom.
- (ii)** This part was answered very well.
- (c) (i)** Many candidates wrote '2p electrons', confusing atomic with molecular orbitals.
- (ii)** Nearly all candidates answered this part correctly.
- (iii)** Some candidates were not specific enough when referring to strong bonds; reference to the C-F bond was required.
- (d)** Some candidates identified the deprotonation of the diol but many other suggestions were seen, such as redox reagent and catalyst.
- (e) (i)** This part was very well done.
- (ii)** The structures given were mostly correct.
- (iii)** The structures given were mostly correct.
- (iv)** Most candidates answered this part correctly.

- (v) Quite often the name given was incorrect. Candidates were provided with information to deduce this.
- (vi) Some candidates were able to relate the size of the cavity to the size of alkali metal ion.
- (f) (i) This part was very well done by candidates, though a few confused empirical and general formulae.
- (ii) Despite the prompt in the question many candidates showed double bonds in the structure.
- (g) (i) This part was well done.
- (ii) This part was well done.
- (iii) It was disappointing to see many cyclic and branched chains, and formulae other than displayed. Many candidates did not realise that but-2-ene has cis and trans isomers or that the products are all straight chain.

Question 5

- (a) This part was done well.
- (b) (i) Many candidates gave either aldehydes or ketones rather than specifying carbonyl group as the required response to the negative 2,4-DNPH test. Carboxylic acids was a common error.
- (ii) While many candidates indicated that compound **C** was oxidised, only a small proportion deduced it must contain primary or secondary alcohols; many candidates gave the answer alcohol or aldehyde.
- (c) While some candidates gave the full detail required, most gained only partial credit by indicating that there were three environments. Many candidates focused on the size of the peaks, which is not a simple indicator of abundance in proton-decoupled carbon-13 NMR as it is in proton NMR.
- (d) Many candidates identified the correct cyclic nature. Credit was given to cyclobutyl structures that were consistent with the data in the question.

Question 6

- (a) Many candidates appreciated that the sodium chlorate(I) oxidised the iodide ions.
- (b) (i) Most candidates correctly stated that it is a slow reaction.
- (ii) Some candidates specified that it was the soluble impurities that were the target of this procedure.
- (iii) Many candidates appreciated that this step was needed for drying the residue.
- (c) The majority of candidates were not familiar with the process described in **step 4**.
- (d) (i) Only a minority of candidates suggested filtration.
- (ii) A small proportion of candidates gave the correct answer of checking the melting point of the product.
- (iii) Most candidates answered this part correctly.
- (e) (i) This part was answered well.
- (ii) This part was answered well.
- (f) (i) This calculation was done well by most candidates.

- (ii) This calculation was also done well, but many candidates quoted decimal places in their answer.
- (g) Some candidates identified the functional group responsible for the peaks rather than naming the impurities.
- (h) Only a small proportion of candidates understood that the question was about solubility.
- (i) (i) Few candidates gained credit here.
 - (ii) Some candidates realised that ethanol contained the $\text{CH}_3\text{CH}(\text{OH})$ group and so would give a false positive result.
- (j) (i) Few candidates gave the correct equation for this part.
 - (ii) Rather than refer to the oxidation number of an element, many candidates referred to a compound or reagent.

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Paper 9791/03
Part B Written

Key messages

Candidates are encouraged to read questions carefully and take care in phrasing their answers; this was particularly noticeable in **Question 2(c)(i)** and **Question 3(b)(ii)**.

General comments

Question 1 was generally well answered but ratioing rates and concentrations was not well understood, nor the clock reaction technique itself. **Question 2** highlighted the benefits of thorough revision and recall, while showing up a general weakness in the understanding of structure and bonding. **Question 3** showed a good understanding of weak acid calculations across the cohort and candidates being able to draw dot-cross diagrams for unfamiliar polyatomic ions. In **Question 4**, the concept of conjugation of alternating double bonds giving a planar structure was little understood, as seen in **Question 4 (b)(i)**. In **Question 5**, the aryl organic reaction mechanism in **Question 5(a)** was difficult for most candidates and few were able to recall this common electrophilic substitution or be able to describe the role of the catalyst. The nature of various functional groups in acidic/basic solutions, or reacting with weak/strong bases, was not well understood by most as evidenced in **Question 5(e)**.

Comments on specific questions

Question 1

- (a) (i) Most candidates drew tangents of good quality; fewer measured the gradients with sufficient accuracy, dividing concentrations by as few as 5 seconds on occasion. The gradients determined were generally accurate. A number of candidates tried to calculate a rate from the graph without using a tangent.
- (ii) Many candidates were unable to use a ratio of the concentrations and their rates correctly to show that one was the approximate square of the other. Most of them saw a reactant concentration fall with a curve and assumed first order, with an attempt at justification. Credit was given for correctly reading the concentrations at $t=0$ and $t=20$ s.
- (iii) Many candidates were able to explain why a large excess of Fe^{3+} gave an approximately constant $[\text{Fe}^{3+}]$, but a significant number incorrectly thought it was to make I^- the limiting reagent or that this made $[\text{Fe}^{3+}]$ constant, which are incorrect.
- (b) Most candidates, having the order with respect to $[\text{I}^-]$ correct, were able to deduce from the table the order with respect to $[\text{Fe}^{3+}]$.
- (c) Almost all candidates were able to write a rate equation consistent with their previous conclusions.
- (d) (i) Most candidates answered well and units were almost always consistent with the rate equation given in (c). Occasionally data was used from (b) rather than (a) and credit could only be given for the units.
- (ii) Some good answers were seen where candidates understood that the rate constant had to be involved in the comparison between experiments at different temperatures where the concentrations differed, and so a calculation was needed here. Many candidates simply compared the rates from (a) and (b) and tried to form a conclusion or compared the rates with $[\text{I}^-]$ while

ignoring the change in $[\text{Fe}^{3+}]$. A few candidates answered without showing the result of a calculation and so did not gain credit.

- (e) (i) Most candidates were able to recall this equation, but a few thought the iodine was a solid. A significant few did not include state symbols.
- (ii) Almost all candidates received credit for the oxidation numbers of iodine and iodide, with far fewer giving creditworthy answers for sulfur in the tetrathionate ion.
- (f) (i) A majority of candidates were not able to explain why the initial rates are normally lower in clock experiments, showing that more understanding of this technique is required. 'Human error' was a common incorrect response.
- (ii) Most candidates who gained credit in (f)(i) were able to obtain credit here but these were a very small proportion of the cohort.

Question 2

- (a) Almost all candidates were able to recall the two arrangements of close-packed layers in metals. Candidates then went on to correctly associate the arrangements with the names, but too many did not give enough detail, describing CCP as 'ABC' rather than 'ABCABC' and/or HCP as 'AB' rather than 'ABAB'.
- (b) (i) Most candidates were able to gain credit here. Candidates should be aware that 'smallest' needs to be qualified in this context.
- (ii) This recall question was generally well answered, although a few candidates incorrectly gave HCP as one of the structures.
- (c) (i) The Born-Haber cycle required attention to detail and a good appreciation of each energy change. Almost all candidates gained some credit with a significant number being awarded full credit. Almost all candidates appreciated that with the positive enthalpy direction given on the diagram, the electron affinity arrow should go down rather than up.
- (ii) Many correct answers were seen here. The most common errors were the sign of $\Delta_f H^\ominus$ (PbF_2) and/or not doubling $\Delta_{\text{at}} H^\ominus(\text{F})$ and $\Delta_{\text{EA}} H^\ominus(\text{F})$.
- (iii) Few candidates gained full credit here. While a discussion involving electronegativity is relevant, the size or polarisability of iodide compared with fluoride was too rarely seen as the answer. More candidates identified the larger covalent character of the PbI ionic bond.
- (d) (i) Almost all candidates gained full credit, with only a few incorrectly opting for square planar.
- (ii) A good proportion of candidates could recall this equation but a significant minority thought either the decomposition was a reaction with O_2 or involved production of Pb metal.
- (iii) Few candidates gained full credit for this question. Candidates could not see that PbF_4 , with its large difference in electronegativity, was an ionic lattice while PbCl_4 must be molecular as it is a liquid. These structure types needed to be stated to gain much of the credit.

Question 3

- (a) Most candidates saw ferritin as just a store of iron rather than something that stores and releases it in a controlled fashion, controlling the levels in the blood. More candidates correctly described the role of myoglobin, with the most common mistake being the word 'transport', a confusion with haemoglobin.
- (b) (i) Almost all candidates could correctly state the coordination number.
- (ii) The weak acid calculation was well done by most candidates. Occasionally there was confusion with a buffer calculation and the Henderson–Hasselbalch equation was incorrectly invoked. Where

the initial RFM was incorrectly calculated, full credit was given for further correct calculations using the incorrect value.

- (iii) This was not well answered by most candidates who did not see the question in the context of what had come immediately before. The most common incorrect answer was from candidates who spotted that lilac/purple is the complementary colour of yellow and so thought the complex was absorbing lilac frequencies while transmitting yellow.
 - (iv) Very few candidates gained credit here. While most could see that Fe^{2+} was less charge-dense than Fe^{3+} , few could then describe the effect of this on the water ligands. A significant majority could only describe a weaker acid as one which dissociates less.
- (c) (i) This was not well answered by the majority of candidates. It should be a well known redox equation but candidates seemed unable to recall it and many different, incorrect half equations were seen.
- (ii) More candidates were able to gain credit here but too often potassium salts or iron oxides were given as answers.
- (d) (i) Most candidates gained full credit here.
- (ii) Almost all candidates gained credit, with the majority gaining full credit.
- (iii) This was very well answered with the majority of candidates able to correctly write the formula for the complex and draw an accurate, clear 3D diagram.

Question 4

- (a) Please note that due to an incorrect name given in the question, all candidates were awarded full marks for the whole of part (a). The published paper has the name corrected. The published mark scheme reflects this change.
- (b) (i) Most candidates did not answer this question well. Most could see that sp^2 carbon atoms were involved, giving a planar part of the structure, but a fully correct answer involving conjugation was rarely seen.
- (ii) Most candidates needed to provide clearer written answers here in order for credit to be awarded; often Markovnikov's rule was referred to in a very simplistic way which showed little understanding of the mechanism or intermediate. Some very good answers which compared the stabilities of both carbocation intermediates were seen.
- (c) Few candidates responded in terms of the shift in equilibrium position of the reaction in (c).
- (d) This question was generally well answered with candidates understanding that the polymerisation involved the carbon-carbon double bond.
- (e) Almost all candidates were able to identify the correct equation and most could then go on to gain full credit. Common errors were not converting the ΔG value to kJ mol^{-1} or not correctly using the two negative signs in the equation.

Question 5

- (a) This should be a common and well-understood reaction mechanism, but few candidates were able to draw it. Credit was given for using the adduct where it was correctly represented.
- (b) (i) This was well answered by most candidates who could see that substitution into the 2- or 6-positions were equivalent and went on to contrast that with substitution into the 4- position.
- (ii) Some answers were seen in terms of the relative electron densities at each position, but most candidates recognised that substitution into position 2- would be sterically hindered by the methyl group.
- (c) (i) The correct Grignard reagent was seen often here, with the most common error $\text{C}_6\text{H}_6\text{MgBr}$. A few candidates made an attempt with RMgBr .

- (ii) Fewer candidates saw that CO_2 was to be the other reagent.
- (d) This was generally well answered and candidates could see that the order of substitution was important here as the two groups involved directed incoming electrophiles to different positions. A common error was discussion of the activating or deactivating of the ring and a few candidates thought there could be further oxidation of the nitro group or nitration of the methyl group.
- (e) Most candidates gained at least partial credit here. **T** was labelled as a substance in the question and the identity requested for the answer, so candidates were expected to name an acid here rather than put ' H^+ '. The nature of various organic groups in acidic solution or reacting with weak bases seemed not to be well understood.
- (f) (i) Almost all candidates could link a lower $\text{p}K_{\text{a}}$ value to a more acidic substance. Fewer could clearly explain why this was the case. Most could see that the benzene ring was involved, but could not link this clearly to the strength of the OH bond or the stability of the anion formed on dissociation.
- (ii) Almost all candidates could see that ethanol was less acidic than water but few were able to explain concisely why.

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Paper 9791/04
Practical

Key messages

- Key to success is for candidates to remember that the data they collect from their experiments must be used either to perform certain calculations or to reason the identities of unknowns.
- There were examples of candidates carrying out unnecessary tasks, such as converting percentages to masses in **Question 1(c)** or additional chemical tests in **Question 3(b)**.
- Candidates need to prepare for this exam not only by carrying out similar practicals during their course, but by using the actual data from these in subsequent calculations and deductions.

General comments

Many good calculations were seen in **Question 1(c)**. **Question 3** revealed that students would benefit from more practice of qualitative tests, beyond simply looking for colour changes or the formation of precipitates.

Comments on specific questions

Question 1

- (a) The opening parts of this first question were very well handled, with almost all candidates recording in a clear way with appropriate headings the data from their experiment. A few candidates referred to 'weight' rather than 'mass'. Most candidates gave each burette reading to the correct number of decimal places. Almost all candidates obtained titres that were in sufficiently close agreement within only a few attempts.
- (b) This was very well answered. A minority of candidates did not quote their answer to the correct number of decimal places.
- (c) (i) This was a relatively demanding question, in that candidates needed to think through the series of steps which led to the production of solution **FA 4**. Some candidates did not use their average titre value at all but simply used the volume with the stated concentrations of either HCl or NaOH.
- (ii) This part of the question was found to be demanding. Common errors involved simply dividing the answer to (c)(i) by 2 or forgetting the stoichiometric ratio and so simply subtracting from 0.025 their value from (c)(i).
- (iii) Candidates were more able to obtain marks in this part. Credit was awarded for error carried forward from (c)(ii).
- (d) (i) Sometimes this question part was not attempted. Many candidates displayed little knowledge of the solubility of Group 2 metal salts. It should be noted that candidates cannot give, for example, $\text{Ca}^{2+}(\text{aq})$ as a reagent as it needs to be the name or formula of the actual compound.
- (ii) Many candidates gave the right answer but some did not give sufficient detail, sometimes just saying that it was harder to judge the end-point but not explaining why this would be the case.

Question 2

- (a) Some candidates did not give all the data they had been asked to put in the table. Others swapped the masses of the residue and the water lost.

A number of candidates did not record separate masses after each cycle of heating and cooling, despite this being clearly stated in point 9 of the method.

Most candidates were in good agreement with the values provided by the supervisor.

- (b)(i) Most candidates calculated the percentage correctly.
- (ii) Candidates found this challenging. Many turned the percentage values into masses using their initial mass of **FA 5**, instead of treating the percentage values as they might in an empirical formula and simply evaluating the ratio of their percent value of water/18 to $39.0/M_r(\text{SO}_4^{2-})$.
- (iii) Very few candidates took the direct route to this answer, with many turning percentages back into masses. In suggesting the identity of M, nearly all candidates selected a Group 2 metal closest in relative atomic mass to their calculated value; examples of Group 1 or transition metals were however also seen.

Question 3

- (a) A number of candidates chose to deviate from the agreed description of precipitates. They had been told in the question that all the ions, other than H^+ , are those from the Qualitative Analysis Notes. Some candidates noted other precipitates within the range of tests as being soluble in excess of one of the reagents. It was rare to see effervescence in responses.
- (b) This was generally well answered, with the most common errors being noting a white precipitate when $\text{BaCl}_2(\text{aq})$ was added to **FA 6** or a yellow or cream precipitate formed between $\text{BaCl}_2(\text{aq})$ and **FA 8**, presumably because of the colour of the **FA 8** solution present. Many candidates went on to carry out more tests than were requested. Candidates should be discouraged from doing so because this risks incorrect observations from such tests being recorded and the observations may confuse their subsequent analysis.
- (c) Candidates found identifying the ions present a challenging task. This may be because candidates did not focus on the key reactions to help them. In (a), the reaction of a colourless solution **FA 6** with a yellow solution **FA 8** to give a red-brown precipitate should have been sufficient to point the way to OH^- in **FA 6** and Fe^{3+} in **FA 8**, for example. With **FA 6** identified, then the white precipitate that dissolves in excess from the reaction with **FA 9** identifies Zn^{2+} or Al^{3+} .