

# CHEMISTRY

**Paper 9791/01**  
**Multiple Choice**

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

## General comments

The paper consisted of 40 questions which involved choosing the correct answer from four alternatives.

Candidates found the following eight questions the most accessible: **7, 8, 15, 16, 20, 22, 27** and **37**. The eight most challenging questions were **1, 3, 14, 18, 23, 25, 26** and **28**. Some of these questions are analysed in further detail below.

## Comments on specific questions

In **Question 3** candidates needed to compare the bond angles in ethane and ethene. Distractor **A** proved popular.

In **Question 14** the best candidates were not put off by the presence of the deuterium compounds and realised the two  $\text{CH}_3$  groups on the central carbon in propanone meant it would not have any chiral carbon atoms in the reaction given.

**Question 18** showed a spread of answers. This suggests the weaker candidates were unfamiliar with the mechanism of this nitration reaction even though the formula of the intermediate was given.

**Question 26** required knowledge of the hydrolysis of esters, with the sodium salt of ethanoic acid formed. Weaker candidates gave **A** rather than the sodium salt.

**Questions 1** and **28** both arose from syllabus section B2.5 suggesting that this is an area of chemistry which candidates find particularly challenging.

# CHEMISTRY

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Paper 9791/02  
Part A Written

## Key messages

Candidates are encouraged to answer questions directly. Unnecessarily long answers that deviate from the question use candidates' time and can lead to loss of marks if earlier valid points are contradicted.

## General comments

Many fine scripts were seen. Candidates often seemed confident with unfamiliar material – even weaker candidates. Candidates would be well advised, when contrasting two things, to comment on both rather than referring to only one and hoping that their view of the other is understood.

## Comments on specific questions

### Question 1

This question was answered generally well.

- (a) (i) Many variations from the expected depiction were seen. While many were allowed, physically unrealistic ones were not – for example, those with hashed (or wedged) bonds opposite each other in the equatorial plane.
- (ii) Nearly all candidates got this part correct.
- (iii) Care with language was needed in this part, with proper reference to numbers of electron pairs of different type and of their mutual repulsion. Only more able candidates were able to score both marks.
- (iv) Again, candidates need to be clear here, saying that the bond dipoles cancelled each other out.
- (b) This part was answered very well. Even the weakest candidates gained some credit.
- (c) This part was answered well. Most candidates scored full marks.
- (d) This part wasn't answered successfully, eliciting some confused responses.

### Question 2

This question was intended to test a range of physical chemistry, with some more challenging parts towards the end. Candidates were generally able to answer the question well.

- (a) This part was answered well and many candidates, as well as making the key point about the strong triple bond, added that the lack of a dipole made the bond more inert.
- (b) (i) Virtually all candidates got this part right.
- (ii) Most candidates correctly answered this part.
- (c) (i) Many candidates came close to the answer but were often not able to express themselves with sufficient accuracy or precision.

- (ii) While all candidates appreciated that NO was both generated and consumed as the reaction proceeded, only those who made reference to the different steps in the mechanism were given credit.
- (d) Virtually all candidates were able to connect the right number of nitrogen and oxygen atoms in the correct sequence so that valencies could be satisfied. Most candidates were able to account for all the valence electrons and to arrange them in the atoms' outer shells in a logical way, while only the most able could see that the nitrogen atoms, unable to expand their octets, would need to form a dative bond with one of the terminal oxygen atoms connected to them.
- (e) Many candidates were able to complete this moderately challenging enthalpy calculation successfully. The vast majority of candidates who did not get the correct answer were able to score partial credit for working. Candidates presenting a clear cycle were far more likely to avoid errors.

### Question 3

This question tested inorganic chemistry and its overlap with physical chemistry. While all candidates were able to gain some credit, few scored very high marks.

- (a) The three graphs required successively more knowledge; this was reflected in the difficulty that candidates had in scoring the marks.
- (b) Many candidates did not make a complete distinction between the structure types, i.e. simple for  $\text{SiCl}_4$  and giant for  $\text{NaCl}$ . Many weaker candidates discussed sodium chloride using a covalent molecular approach.
- (c) While a lot of variation was allowed in candidates' responses, the equations for the bromide and iodide reactions proved challenging for all but the most able candidates.
- (d) Most candidates were able to recall this equation.
- (e) (i) Most candidates scored at least partial credit.
  - (ii) In making a proper comparison candidates had to point out – in addition to the sulfur atom possessing a lone pair of electrons – that the carbon atom did not have such a lone pair. Many candidates did not make this point.
  - (iii) Candidates needed to be precise about what happens and what is doing it; imprecise answers were not allowed.

### Question 4

This question tested candidates' knowledge of some fundamental aspects of organic chemistry and their application to solving problems. The final part of the question involved a novel context and a difficult problem which stretched the most able candidates.

- (a) (i) This part was not always answered well. A number of candidates wrote an odd number of hydrogen atoms: in compounds with molecular formulae  $\text{C}_x\text{H}_y\text{O}_z$   $y$  must be an even number.
  - (ii) The need to interpret quite a complicated skeletal formula challenged many candidates.
- (b) Able candidates could see that the question was asking for a qualitative test to distinguish between a secondary and a tertiary alcohol. Use of bromine water would necessarily have to be a quantitative test, and so candidates were only able to gain credit with such an approach if it was properly explained how such a quantitative test would be carried out.
- (c) (i) Many candidates were able to salvage unclear explanations with a correct diagram.
  - (ii) Virtually all candidates were able to gain at least partial credit in this part.

- (d) Only a small minority of candidates were able both to specify that it was the  $\pi$  bond which broke and that a C–H bond was formed in the reaction. Nearly all candidates scored the mark about the change in functional group level.
- (e) Most candidates answered this part correctly. Those who did not specify a valid halogen in the Grignard did not gain credit.
- (f) (i) This part was answered well.
- (ii) Many candidates got one or two structures correct but only the most able got three.

### Question 5

This short question examined some atomic and physical areas and was answered well.

- (a) (i) This part caused very few problems for candidates.
- (ii) This was another straightforward part for candidates.
- (b) Virtually all candidates were able to gain some credit, but only the most able kept charges balanced throughout and appreciated that the second electron affinity of selenium had to be endothermic.
- (c) This was well recalled.

### Question 6

This question tested candidates' knowledge of organic and analytical chemistry and involved some problem solving. It was generally answered quite well.

- (a) (i) While there was some flexibility in the marking of structures, physically unrealistic 3D depictions were not given credit. For example, the hashed and wedged bond must lie within the reflex angle part of the bonds in the plane connected to the chiral carbon.
- (ii) This part was answered well by many candidates.
- (b) (i) A common error was the statement that the combined relative mass of two oxygen atoms is close to 31.4% (this arises by chance as the molecule has a relative mass close to 100). More able candidates gave clear explanations.
- (ii) This part was generally answered well. Some candidates gave pentanoic acid as one of their answers. While this wasn't credited, an error-carried-forward mark was available for correctly stating in the next part how many  $^{13}\text{C}$  NMR signals this molecule gives.
- (iii) Nearly all candidates were able to gain at least partial credit in this part. Few candidates were unable to identify the carbon giving the signal at 180 ppm and most could ascertain the correct number of signals in at least one of their given structures.

### Question 7

This question tested candidates' knowledge of practical organic chemistry and contained parts that challenged the most able candidates.

- (a) Nearly all candidates got this part correct.
- (b) Many candidates got this part correct. A common error was to say that the sulfuric acid is toxic.
- (c) This fiddly calculation was done well. Candidates getting it wrong generally picked up most of the marks as credit was given for errors carried forward correctly. Accounting for reaction yield was the most challenging part.

- (d) (i)** Most candidates appreciated what the question was asking for, even it wasn't always very clearly expressed.
- (ii)** Nearly all candidates got this part correct.
- (iii)** A common error was to think the purpose of the anhydrous calcium chloride was anti-bumping. Dehydration wasn't given credit.
- (iv)** This question was marked quite flexibly, though a method had to be given, rather than just saying 'without a naked flame'.
- (v)** Many candidates realised that the intermediate alkene would be a gas at r.t.p. or would at least be much harder to condense.
- (e) (i)** Quite a common response was that the water was to stop the bromine reacting with the air, which was not given credit.
- (ii)** Virtually all candidates pointed to the difference in density between bromine and water. Credit was not given for 'bromine is insoluble in water' or 'water is insoluble in bromine' since bromine water is a known reagent.
- (iii)** This part was generally answered well, showing an appreciation of laboratory technique.
- (iv)** Most candidates gained partial credit on this part. Only clear answers making reference to the transformation occurring in the organic layer and how the resulting increase in density of the layer eventually reaches the critical value of  $1.0 \text{ g/cm}^3$ , after which the layer sinks beneath the water, gained full credit.
- (f) (i)** This part was answered well.
- (ii)** Only more able candidates were able to appreciate this subtle practical point.
- (iii)** This part was also well answered by the more able candidates.

# CHEMISTRY

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Paper 9791/03  
Part B Written

## Key Messages

Candidates are advised to plan the key points for answers that involve more than a simple recall of fact. This will make more likely they cover the key points and do not contradict themselves.

## General Comment

Most candidates had prepared well and scored highly on the easier parts of the paper such as much of **1(a)**, **1(b)** and the opening sections of **3(a)**, **3(b)** and **5(a)**. Where candidates found the paper most challenging was in discussing lattice energies in **4(a)** and the final NMR question. In tackling the more extended written answers candidates need to consider carefully what are the key relevant facts and not deviate into other areas.

## Comments about specific questions

### Question 1

- (a) (i)** The majority of candidates worked out half-lives but some did not go quite far enough to show they knew exactly what they were doing and so for example quoted the first as 1100 and the second as 2200. A number of candidates chose to work out the rate at different concentrations by drawing tangents to the curve at relevant points. They then showed that these linked the rate and concentration as being proportional to one another. A few candidates tried to show that the time for the concentration to drop by an equal amount was the same.
- (ii)** This was well answered.
- (iii)** Almost all candidates accessed the correct equation from the *Data Booklet*. Although here there was no penalty for doing so, candidates should be reminded that selecting data points as far apart as possible will lead to more accurate answers. Some candidates selected a time of only 250 s. A number of candidates gave units for  $k$  involving mol and  $\text{dm}^3$ .
- (iv)** This was very well answered, although candidates should be encouraged to describe it as the slowest step rather than simply the slow step.
- (v)** Candidates found this quite challenging as although many got the mark they required many lines of working when what was needed was to write out all the reactants and products and then show that cancelling affords the overall reaction.
- (b) (i),(ii)** The majority answered these parts correctly.
- (iii)** Again this was well answered. The majority of candidates obtained the answer by constructing the appropriate ratio using one of the given rates in the table but some went via the calculation of  $k$  and so pre-empted part **(v)**.
- (iv),(v)** Again these were extremely well answered.

## Question 2

- (a) (i) Almost all candidates knew this definition.
- (ii) Again this was well answered although some candidates could have made the pairs clearer.
- (b) (i) This was a challenging question and a significant number of candidates did not appreciate that what they need to show was that  $[\text{HC}\ell]_i = [\text{H}^+]$  by using the volume and concentration data to determine  $[\text{HC}\ell]_i$  and the given pH to work out  $[\text{H}^+]$ . A significant number became distracted by other data and so, for example, starting working out the total concentration of chloride.
- (ii) This was well answered.
- (iii) On the face of it this is simply a buffer type calculation albeit slightly more challenging in aiming for a value for  $K_a$  rather than a value for the pH. Nevertheless candidates again struggled. It was necessary to appreciate that if  $[\text{HA}] = [\text{A}^-]$  then  $\text{pH} = \text{p}K_a$  and for the closing two marks to explain how this buffer responds to the addition of acid.
- (iv) This was better answered and most calculated a value based on their previous value of  $K_a$  or on the value given.
- (v) Overall this was well answered.
- (c) (i) Of the five possible marks most candidates scored the first by starting the sketch at a volume of pH that corresponded to that calculated in part (iv). The next most awarded mark was for ending the curve within the appropriate pH range. Next was the mark for a vertical rise at  $30 \text{ cm}^3$ . The two least awarded marks were for the pH at half-equivalence. As with (b)(iii), Many candidates did not use the fact that at half-equivalence  $\text{pH} = \text{p}K_a$ . The least awarded mark was for recognising the area of the sketch which corresponds to the solution acting as a buffer, despite the earlier parts of the question having been about buffers.
- (ii) This was well answered. Candidates are reminded in such questions to make their reasons for their choice very clear by linking to the  $\text{p}K_a$  of the indicator.

## Question 3

- (a) (i), (ii), (iii) For the vast majority of candidates this question opened well and they scored nearly all the marks available from these parts. In (ii) more offered ether than glycosidic for the type of link in C, while some did not score the mark by suggesting A showed a peptide link. Occasionally ether and ester were confused as were amide and amine.
- (iv) This was more challenging but many candidates picked up both marks. The weakest answers saw the benzene ring involved in the polymer chain.
- (b) (i) This was very well answered with most candidates picking up at least 4 or 5 of the available marks.
- (ii) Again this was well answered although some candidates omitted the fact that the solution must be acidified and so did not score the mark.
- (iii) This was less well handled. A number of equations showed  $\text{H}_2$  as a product while in others, even when the products were correctly given, the equation was not balanced.
- (iv) In general this was well answered but many candidates could have been much more concise in their answers. Some lost marks by becoming confused over which reaction was which and ended up contradicting a correct statement they had given earlier in their answer.

#### Question 4

- (a) (i), (ii) Both these parts were poorly answered. In (i), a large number of candidates started their explanation for the trend in the  $\text{CuX}$  and  $\text{CuX}_2$  lattice energies by talking about the stability of  $\text{Cu}^+$  and  $\text{Cu}^{2+}$  in terms of electronic configuration and did not refer to either the charge or the size of the ion. Most common was to award the mark for noting the increasing size of the halide ion down the group. Very few candidates referred to attraction between oppositely charged ions or linked this to the value of the lattice energy. In (ii) the most commonly awarded mark was for noting the increased covalent character in the bonding of  $\text{CuBr}_2$  but in contrast the other marks were rarely awarded.
- (b) (i) This was rarely calculated correctly. Where candidates had used the correct values of +0.36 V and +0.15 V in their answers they more often gave +0.21 V as the answer rather than adding the values to give +0.51 V.
- (ii) Few candidates scored both marks here.
- (iii) The steps from the value of standard electrode potential were nearly always executed correctly but not all candidates worked out this initial calculation correctly.
- (iv) This part proved challenging.
- (c) The identification of **W** as  $\text{CuO}$  and the equation showing the thermal decomposition of  $\text{CuCO}_3$  were well managed. Few candidates identified **X** as  $\text{Cu}_2\text{O}$  but rather suggested that **X** was  $\text{Cu}$ . The equation showing  $\text{CuO}$  decomposing to  $\text{Cu}$  and  $\text{O}_2$  was credited for these candidates. Again a large number of candidates identified **Z** as  $\text{CuCl}_4^{2-}$  while slightly fewer also assigned **Y** as  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  and also gained the mark for having the coordination geometry of these ions. The remaining equations proved more challenging.

#### Question 5

- (a) (i) Almost all candidates were able to score this mark. Some answers could have been clearer, for example with references to the molecule being rotated.
- (ii) Most candidates drew the correct orientation but again explanations could have been clearer and there were a noticeable number who referred to priority being linked to atomic mass.
- (b) (i) Nearly all candidates talked about nuclear spin in some way and so scored this mark.
- (ii) Again answers here were not always clearly stated and although the mark was largely awarded, candidates should be reminded to make the link between two quantities clearer. For example it was fine to say 'shielding caused signals to move to a lower chemical shift' but much better would be to say that 'an increase in shielding caused signals to move upfield and so to a lower chemical shift'.
- (c) This proved to be a very challenging part. Virtually all candidates recognised that MHPE must involve a tri-substituted benzene ring but some suggested a structure that did not fit the formula given in the question, occasionally with only 3 oxygen atoms rather than the 4 required. Few candidates made the link to norepinephrine as given at the start of the list of facts about the compound. A number of candidates concluded from the fact about the reaction with  $\text{NaOH}$  that the molecule must contain a carboxylic acid. When it came to the NMR data, the mark for assigning signals **A**, **B** and **C** to OH groups and the final mark for explaining the coupling patterns were both relatively often awarded. The other NMR marks required candidates to have got much closer with their suggested structure for MHPE and consequently were less frequently awarded. Likewise the marks for the equation were rarely given.

# CHEMISTRY

Paper 9791/04  
Practical

## Key messages

In tables candidates should give full entries such that it is clear what is being recorded. Candidates should think more about the chemistry behind the qualitative observations to make sure that their given observations are consistent.

## General comments

Candidates were much more challenged by the final qualitative analysis question than by the quantitative analysis section covered in **Questions 1** and **2**, often obtaining marks that were noticeably lower than in earlier parts of the paper. This is an area that needs further focus better to prepare candidates for future practical papers.

## Comments about specific questions

### Question 1

- (a) Most candidates scored well on this opening question. It is worth noting here (as in **2(a)**) that candidates need to be encouraged to give full descriptions for their entries in tables so it is very clear what is being recorded. When it came to the titration, results were very often extremely close to the supervisor value. A few candidates forgot to record readings to the nearest  $0.05 \text{ cm}^3$  while others recorded their initial burette reading as  $50.00 \text{ cm}^3$ . Almost all candidates knew when they had obtained concordant results.
- (b) This was well answered and virtually every candidate showed how they had arrived at the value for the following calculations.
- (c) (i), (ii) and (iii) These calculations were relatively straightforward and as such the majority of candidates scored highly. Occasionally in (ii) candidates scaled by the wrong ratio using their value from (b) rather than the  $25 \text{ cm}^3$  required.
- (iv) This was often well answered. Of the two main ways to solve the problem, the majority proceeded by working out the relative formula mass of **FA 1** first and then subtracted the relative formula mass of  $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2$ . The other route involved working out the ratio of the amount of water lost to the amount of  $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2$  remaining after thermal decomposition. This was also seen many times. A few candidates proceeded by writing expressions in terms of  $x$  which they then solved successfully.

### Question 2

- (a) Candidates should be encouraged to take care over the exact descriptions for each weighing. For example, 'tube after heating' does not give the precise information of 'mass of boiling tube, wool plug and contents after heating / g'. A few candidates did not record the mass lost but instead noted the mass of **FA 5** that remained, although really this heading should be 'mass of residue' or 'mass of  $\text{CuO}$ '. Comparison to supervisor's results were, as in **1(a)**, very good indeed.
- (b)(i) This was well answered and the majority of candidates gained the two marks available for this part.

- (ii) and (iii) Although more challenging than the opening sections this again was generally well answered. Of the two parts, (iii) proved more difficult with some candidates dividing by  $y$  and so leaving themselves with a much more difficult task in (v). A few candidates gave a much more extensive expression by working out the mass of water lost as the total mass lost minus the mass of  $\text{CO}_2$ , expressed as 44 multiplied by their expression in (ii). They then divided this expression by 18.
- (iv) Again this was well answered. The simplest expression as in the mark scheme was often taken a little further which simply helped in the solution to (v).
- (v) Again this was well answered. A few candidates arrived here with quadratics to solve but many did so successfully. Other earlier errors or poor experimental results led to values of  $x$  which were negative. Candidates who had the courage just to state this got the mark but others dropped the sign in the working and so did not score.
- (c) This was not quite as well answered. Although there were many who went straight to the right answer, there were also many examples of more vague comments such as 'heat for longer', or 'remove the ceramic wool plug' etc.

### Question 3

- (a) The choice of correct reagents to identify the cations was straightforward for candidates and most managed to draw up a single table without any repetition of headings. Although there was no need to use both  $\text{NaOH}$  and  $\text{NH}_3$  almost all candidates chose to do this. A few then did not obtain the observation marks as they made inaccurate observations with the additional reagent. Those candidates with the correct observations always managed to identify the cations correctly. A few candidates misinterpreted the colour of  $\text{Fe}(\text{OH})_2$  and so instead went down the path of assigning the cation in **FA 7** as  $\text{Cr}^{3+}$ . A small minority assigned **FA 6** as containing the  $\text{Fe}^{3+}$  cation as a result of the precipitate darkening to brown over time.
- (b) (i) A number of candidates did not record that the  $\text{KMnO}_4$  solution was decolourised on addition to **FA 8**. With **FA 9** a number did not score the marks as they identified the precipitate as being purple in colour. This suggests that they added too great a volume of  $\text{KMnO}_4$  and so the solution became very darkly coloured.
- (ii) Most candidates scored this mark although some did not note the white precipitate with **FA 9** as being soluble in aqueous ammonia.
- (iii) The reaction of acid with **FA 8** proved the most challenging of this set of observations. To score the mark candidates needed to note both the effervescence as well as the brown gas. It may be that candidates simply did not agitate the tube sufficiently or wait a few moments.
- (iv) This was very straightforward although a handful of candidates did not score the mark as they observed effervescence with **FA 8** and  $\text{AgNO}_3(\text{aq})$ .
- (v) This was well answered. Chloride was identified more often than nitrite although occasionally bromide was suggested if the candidate had noted cream precipitate in the preceding tests. In place of nitrite the most common suggestion was either chloride or sulfite.
- (vi) Very few candidates identified the white precipitate in test (ii) with **FA 8** as  $\text{AgNO}_2$ . Most did not seem to note that test (iv) is identical to test (ii) apart from the solution having first being acidified and that this must then form part of the explanation for the different observations.