

CHEMISTRY

Paper 9791/01
Part A Multiple Choice

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

General Comments

The paper consisted of 40 questions which involved choosing the correct answer from four alternatives. This was the last paper to be set solely on Part **A** of the syllabus. From 2016 questions on both Part **A** and **B** of the syllabus will be included.

Comments on Specific Questions

The nine easiest questions were **2, 3, 4, 6, 14, 16, 21, 32** and **36**. These were largely non-calculation items requiring only one or two pieces of straightforward factual recall to get to the answer.

The six questions that candidates found most challenging were **13, 17, 19, 24, 26** and **31**.

Question 13 required candidates to apply knowledge of hydrogen bonding to unfamiliar molecules. Many candidates did not assign the linear F---H-F system to **C**.

A significant proportion of candidates in **17** spread their answers between **B**, **C** and **D**, not appreciating the role of H^+ ions in the equilibrium.

In **19** most candidates knew gas X was hydrogen chloride. However half of these did not realise the chloride ions in Y were initially in an environment of excess aqueous ammonia and so would not precipitate silver chloride.

In **24** the best candidates balanced the combustion equation producing CO_2 , CO and H_2O correctly to give **D**. Many candidates gave **A**, suggesting they omitted to take account of the H_2O formed.

In **26** a significant proportion of candidates gave **B** assuming the isomers were $CH_3CHClCN$ and CH_2ClCH_2CN . A minority deduced the former had optical isomers so giving **C** as the answer.

Question 31 also involved isomerism and caused similar problems. Many candidates gave **A** suggesting the isomers were but-1-ene and but-2-ene. They did not appreciate but-2-ene had *cis-trans* isomers so giving **B** as the answer.

In past papers many candidates have struggled with spectroscopy items – syllabus **section A4.2** to **A4.5**. It was therefore good to see **Questions 36-40** were well answered by the majority of candidates.

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Paper 9791/02

Part A Written

Key Messages

General Comments

The practical-based question, **Question 5**, was more challenging than some, but use of error-carried-forward marking meant that candidates were not unduly penalised. Candidates had a very good appreciation of the practical skills required for accurate titration. Candidates found **Question 2** challenging. They were also pushed quite hard by the stereochemistry question, **Question 3**, which included many chiral centres and molecular symmetry, but performed well. The first question on the paper was straightforward and done very well.

Comments on Specific Questions

Section A

Question 1

This question was intended to be a fairly easy opener and was done very well by candidates.

- (a) (i) Most candidates scored well. Any mention of substances being in the gas phase negated reference to standard conditions.
- (ii) This standard calculation was done well.
- (b) (i) Again, a standard calculation that caused few difficulties.
- (ii) Credit was given to arguments based on the equilibrium or on the kinetics, making the question accessible to all candidates.
- (c) (i) Most candidates answered this part correctly.
- (ii) Some candidates forgot to have a carbon branch and drew all three carbons in a line; otherwise this part was answered well.
- (d) (i) This part was answered correctly by most candidates.
- (ii) Some candidates thought the sulfur was acting as base, but most answered correctly.
- (iii) This was the most discriminating part of the question, with only stronger candidates seeing how to combine the equations and arrive at the correct sign for the answer.
- (iv) The majority of candidates answered this part correctly.

Question 2

This question saw a mixed performance.

- (a) (i) Many candidates did not see the simple ratio, which is all that is required to answer this part.
- (ii) Many candidates got into difficulties with the different quantities. Inadequate explanation of steps and omission of units probably accounted for some of the problems.
- (b) (i) Most candidates appreciated the mole ratio that is involved in the question. Those who slipped up earlier in the question usually picked up error-carried-forward marks.
- (ii) Only a minority of candidates did not know this pH value.
- (iii) Most candidates appreciated that the excess sodium would create an alkaline solution. Some candidates lost the mark because they did not balance the associated equation.
- (c) Many candidates believed that aluminium chloride reacted with water to produce aluminium hydroxide. (Partial credit was given for the generation of HCl in solution from this hydrolysis.) A minority candidates believed that it was the aluminium that reacted with water.
- (d) (i) Many candidates wrote one or both of the two products as acids. In the naming part, credit was only given for chlorate(I) and hypochlorite (many other variants were seen).
- (ii) This part was generally answered well.

Question 3

This question was generally answered well.

- (a) (i) Most candidates scored well on this part.
- (ii) Many candidates lost credit with loose definitions, omitting mention of carbon-12 or isotopes.
- (iii) Most candidates were able to calculate the relative atomic mass; the main error was not following the instruction to give the answer to one decimal place.
- (b) (i) This part was answered very well.
- (ii) Many candidates appreciated that there was no net dipole in the molecule. Credit was also given to other arguments that were chemically reasonable.
- (iii) Most candidates got this part correct. Some candidates drew the repeat unit rather than the monomer.
- (c) (i), (ii) Most candidates realised that both parts referred to the syllabus points about F_2 and HF . Common errors included answers to (i) that were not diatomic molecules and answers to (ii) that were not covalent bonds.
- (d) (i) Most candidates realised that the reaction is some sort of addition; reduction is also acceptable.
- (ii) This part was generally answered well.
- (e) (i) Nearly all candidates realised that this question could be answered by analogy with the disubstituted isomers of benzene.
- (ii) This part had been considered among the hardest in the paper, but many candidates not only drew the positional isomers correctly but saw the enantiomeric relationship as well.
- (iii) Only a minority of candidates scored this mark, with most either failing to remember the isomer with all fluorines pointing in the same direction or believing there were additional isomers with four and five fluorine atoms pointing up.

Question 4

This question discriminated between candidates well.

- (a) (i) The majority of candidates scored well on this part.
- (ii) Most candidates thought to write the analogous FGL1 compound.
- (b) (i) This part was generally answered well.
- (ii) Most candidates reduced the nitrile to an amine though some also reduced the $-OH$ to $-H$ as well.
- (c) (i) Only more able candidates realised the compound must be cyclic.
- (ii) Some candidates struggled with this part.
- (d) This required candidates to assimilate the details and realise the molecule must be symmetric around a single carbon with four $-OH$ groups.
- (e) (i) The key step in the question was to see (using the molecular formulae) that the nitro group must substitute for an H atom and that this is bound to be the H on the $-OH$ group. Error-carried-forward credit was therefore given to those candidates who applied this idea correctly to a structure they gave in the previous part. No credit was given for substituting a C–H hydrogen with the nitro group, which was a common error.
- (ii) Most candidates realised that water was the logical product. A common error was hydrogen.
- (f) (i) This part was answered quite well.
- (ii) There are actually quite a few structures that satisfy the molecular formula and the requirement of a single environment for each element (e.g. using a valency of sulfur higher than 2, a ring of sulfur or of carbon – even multiple rings are possible). Credit was given to all answers that satisfied these requirements.
- (g) Almost all candidates realised the basic synthetic strategy. Some candidates lost marks for writing unbalanced equations. As long as equations were balanced acceptable variants on the hydrolysis products were given full credit. Ions alone, e.g. $Cr_2O_7^{2-}$, were not accepted as reagents: the whole compound was required as the reagent that is used.

Question 5

This question, requiring the assimilation of a lot of information in an unfamiliar context, also discriminated well between candidates.

- (a) (i) Even the weakest candidates generally got this part correct; however, there was no flexibility in the ordering of the elements in the formula: the convention given in the syllabus had to be followed.
- (ii) This part was answered well; however, there was no tolerance of $-HO$.
- (b) (i) Some candidates could see that three moles of pyridine are required, however most answered with one or two moles.
- (ii) Most candidates could see that pyridine was accepting a proton and so answered correctly.
- (iii) Many candidates answered that HI is pale yellow. Only a minority of candidates realised the colour is due to the tiny excess of the iodine in the Fischer reagent.
- (iv) Many candidates took notice of the reversible reaction arrow in the first equation and gave the Le Chatelier explanation.
- (c) This part was generally answered well.

- (d)(i)** Most candidates correctly calculated the required mass of iodine, but only a minority dissolved it into solution outside the volumetric flask. Many struggled with the volume of pyridine required – a common error being to assume that the number of moles required was the stoichiometric coefficient rather than a quantity related to the amount of iodine. Those who realised the amount of pyridine is a multiple of the amount of iodine and required that volume or more in the Fischer reagent received full credit even if they were using an incorrect mole ratio (for which they had already been penalised). Most candidates showed a good appreciation of the safety requirements given the hazards specified. Credit was given for knowledge of good experimental technique in the preparation of a standard solution, e.g. transferring with washings and inverting the volumetric flask after it has been made up to the mark.
- (ii)** Most candidates suggested thiosulfate to dispose of the iodine, but many also suggested setting fire to the methanol.
- (iii)** This part was answered extremely well, with many candidates scoring more marking points than the maximum mark for the question part.
- (iv)** Most candidates made the connection with the earlier statement that methanol absorbs water from the air.
- (v)** Being a 'show' question with the 'answer' given as part of the question, this part was marked quite strictly.
- (vi)** Only a minority of candidates were able to score full marks for this question. All four marks were effectively stand-alone and many error-carried-forward marks could be given. This meant that candidate scores for this part were spread over the range of marks, giving a good discrimination.

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Paper 9791/03
Part B Written

Key Messages

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

General comments

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

The best responses were distinguished by their clarity where explanations were required notably in **2(c)(ii)** and **(iii)**, **3(a)**, **4(c)(iii)**, and **5(b)(iv)**.

Comments on Specific Questions

Question 1

This question tested candidates' knowledge and understanding of ideas related to half cells, cell diagrams and free energy calculations.

- (a) Part (i) was generally well answered although a significant minority of candidates mistakenly referred to the cathode as the negative electrode. In part (ii) many candidates put the Pt electrode on the wrong 'end' of their diagram and many failed to remember the need for the higher oxidation state species (O_2 in this case) to be next to the salt bridge. Part (iii) was well answered but many candidates forgot to include a sign or came up with a negative answer. In generating the half-equation in part (iv) many candidates simply attempted to create the overall equation by introducing $1/2O_2$ to react with the CH_3OH and producing $4H^+$ and $4e^-$, not realising that the C is changing oxidation state from -2 to $+4$ so $6e^-$ are needed here.
- (b) The frequent use of $4e^-$ in (a)(iv) led to many 'wrong' answers here but ecf was applied to avoid a double penalty. Parts (ii), (iii) and (iv) were generally well answered although there was some confusion with the consistency of units between ΔH and ΔS . In (iv) candidates must remember to make clear whether they are referring to 'above' or 'below' the calculated temperature. A phrase such as 'this is the temperature at which the reaction stops being feasible' is not enough.

Question 2

This question tested the application of ideas related to periodicity and transition metals

- (a) Most candidates recognised the need to mention constancy of shielding as well as increasing nuclear charge but must remember that a phrase such as 'pulls the electrons in closer' is not equivalent to the idea of a stronger attraction/pull, as required in the MS, as this is simply a repeat of the data given about decreasing radius.
- (b) Most candidates produced a correct explanation in (i) but (ii) proved more challenging with many attempted answers too complex.

- (c) This question was well answered by many but a lack of clarity cost some marks. Many answers in (ii) implied that the three lower energy orbitals experience no (rather than a lesser) repulsion as a result of their position between the Cartesian axes while others did not make clear that 'repulsion' was involved. In (iii) a significant minority produced answers implying that the colour seen is due to an emission rather than being the complementary colour following absorption.
- (d) This was generally well answered although again a lack of clarity in (i) cost some candidates a mark.

Question 3

The contrasting choice of conditions required to bring about elimination or nucleophilic substitution in the reaction of a halogenoalkane and alkali formed the basis for this question, which also developed a comparison of the S_N1 and S_N2 mechanisms.

- (a) This proved to be the most challenging question on the paper with the majority of candidates trying to incorporate a standard hydrogen electrode into their answer. Only the very best candidates were able to break down the overall equation into its component half-equations and so suggest appropriate components for each half-cell.
- (b) This was generally well answered but the mark was occasionally lost by a failure to relate a generic definition to the specific equation given.
- (c) In part (i) a significant minority included copper on the top of the expression. In (iii) rearranging an expression with a squared term often caused problems.
- (d) This was generally well answered.

Question 4

This question was based on Grignard Reagents, esters and benzene rings.

- (a) In (ii), although the equation for Step 1 was well remembered Steps 2 and 3 were more confused.
- (b) Parts (i) and (ii) were generally well answered although identifying the monomers was challenging for some. In (iv) many candidates either failed to give the anionic product for the dicarboxylate or else mistakenly also gave an anionic version of the diol. In (vi) a diphenol was often suggested.
- (c) This was generally well answered although many candidates again struggled with the clarity of explanation in (iii) where the number of marks available gives an indication of the depth required.

Question 5

This question tested a variety of skills related to reaction rates, order and isomerism.

- (a) A number of answers were seen suggesting a transformation of fructose into glucose or that more fructose was produced than glucose, despite the opening sentence in the stem of (a). The rest of (a) was generally well answered although many candidates assumed the units were s^{-1} in (iii) without converting from the units given of 'min'.

- (b) Most sections were generally well answered but, in part (iv), candidates need to be very clear when explaining the order of the groups being viewed clockwise. The fact that most candidates are taught to number the groups from 1 to 4 (i.e. an increase in number) in order of decreasing priority means they need to be very careful when referring to the fact that the *R*-isomer is the one in which the groups are seen to **decrease** in priority clockwise (when the lowest priority group is placed at the rear). Candidates will find it easiest to select the correct version of their isomers if they actually draw the diagram with 'H' at the rear – i.e. the dashed line. In part (v) the idea of a racemate earned most candidates a mark but fewer referred to the lack of stereoselectivity of the H⁺ or the optically inactive product.
- (c) This was generally well answered but some candidates confused it with nucleophilic substitution and referred to a planar 'intermediate' rather than recognising that it is the carbonyl carbon itself that is planar here.

Question 5

This question was an organic identity question based on NMR and IR but with some additional sections on the background understanding of the process.

- (a) Most candidates correctly identified the carboxylic acid but must ensure that the detail of the interpretation of splitting patterns and IR peaks is correctly explained. The same comment applies to the ester in (ii). In the absence of supplied chemical shift data it was decided to allow methyl propanoate as an alternative answer to (ii), although it had been hoped that the relative positions of the singlet and the quadruplet might allow the distinction between ethyl ethanoate and methyl propanoate to be made.
- (b) Explanations of (i) and (iii) were often muddled, making it clear that many candidates can draw the conclusions when interpreting NMR spectra but are weaker on the fundamental principles. The idea of a difference in energy corresponding to frequencies of radio-waves was often missing in answers to (i) whilst many failed to make clear what shielding was actually caused by in (iii).

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Paper 9791/04

Practical

Key Messages

Candidates are encouraged to take time to read any preliminary information given in order to gain a sound level of understanding of the experiments performed. This greater understanding will help with later questions. Candidates should also take time to plot points carefully and to select scales that are less likely to lead to plotting errors.

General Comments

This year's paper presented candidates with a number of challenges both in terms of some practical skills and in terms of subsequent calculations and discussion. Some practical aspects were well handled with excellent results in **Question 1(a)** but observations in **Question 2(a)(ii)** showed that many students had not taken enough time to prepare the mixture before separating it. In the qualitative analysis questions, **Questions 2** and **3**, it was clear that where tests were carried out accurately then students had no real difficulty in drawing conclusions. In **Question 1**, however, many students struggled with questions that sought to test a deeper understanding of the experiment and these proved to be among the more challenging questions on the paper.

Comments on Specific Questions

Question 1

- (a) This was very well answered with nearly all candidates making an excellent start to the paper. The majority of candidates followed the constraints set for the further three volumes although a handful did select volumes great than 20.00 cm^3 of **FA 1** and so were not able to obtain useful results. Agreement with the values provided by the supervisor was excellent with a large majority of students securing both accuracy marks. In addition, there was also an excellent level of consistency within candidate results which secured an additional mark. Tables were laid out clearly with attention being given to headings and units.
- (b)(i) This proved to be challenging as many candidates did not make full use of the information provided at the start of the question on page 2 and as a result it was not uncommon to see calculations here that did not feature thiosulfate at all.
- (ii) This was relatively straightforward and most students scored this mark although it is worth noting that a number did not give their answers to at least two significant figures.
- (c) A significant number of students struggled here. Although the first two marks were almost always awarded, the remaining two marks proved more difficult to secure. Many candidates were not able to plot accurately the points they had calculated in (b)(ii) with a number making an error in the plotting of at least one point, usually the x coordinate. Far fewer had problems with the line of best fit but there were some answers in which all the points were on or below the line.
- (d)(i) Almost all candidates had a good idea about the answer here but a significant number did not state the need for the line to go through the origin and so did not secure the mark.
- (ii) This was well answered with nearly all candidates giving a correct rate equation.
- (iii) Overall this was well answered with only a few candidates making errors in the reading of points from their line of best fit. Some candidates used data direct from their table in (b)(ii) when these

points did not lie on the line and so did not score this mark. A few candidates omitted the powers of ten when reading the value of rate from the y axis.

- (iv) This proved to be a relatively challenging question. A significant number of students did not see the link between the rate constant, k , and the gradient that they had calculated in (iii). As a result some again used a point on the line and the rate equation from (ii), which then gave them a route to the correct answer. Calculating the initial concentration of the hydrogen peroxide was also not as secure as it might have been, despite the fact that candidates had been shown how to do this for iodide ions in (b)(ii). A significant number of students simply took $[\text{H}_2\text{O}_2]$ to be 0.1 mol dm^{-3} , this being the listed concentration of **FA 3**. Correct units for the rate constant were given by the vast majority of candidates.
- (v) This was a demanding question. Among the weaker answers it was not uncommon to see suggestions that hydrogen peroxide might furnish H^+ ions in solution.
- (e) Again this question proved to be demanding. Many focused at once on the fact that the increase concentration would lead to faster reactions and diminished reaction times but others talked about how the acid was in excess and therefore reasoned that it would have no effect on the rate of reaction.

Question 2

- (a) (i) Overall this was well answered with a number of candidates also going on to note that the precipitate darkened in air.
- (ii) The quality of answer here depended heavily on whether the student had taken sufficient care when stirring **FA 5** in water to make certain that all of one salt had dissolved. If this had been carried out correctly, then part (ii) proved very straightforward to observe the blue solution and subsequent blue precipitate on adding NaOH. Many students also noted effervescence but they did not then test the gas. If **FA 5** had not been stirred sufficiently then the copper carbonate was contaminated with MnCl_2 and this made for a range of invalid observations and difficulties in identifying the ions.
- (b) As noted above this very much depended on the quality of observations particularly in (a)(ii). It was also noteworthy that quite a few candidates who had observed effervescence in (ii) did not suggest the carbonate ion in (b).
- (c) Although many students obtained the first mark for identifying the reagents as silver nitrate and aqueous ammonia, few candidates made the link to the tests in (a) to obtain the second mark and instead talked about the problems of identifying chloride and bromide ions in general.

Question 3

- (a) (i) (ii) Both of these tests were carried out correctly by nearly all the candidates.
- (iii) Again in this test many students secured the mark although some only noted the brown precipitate and did not note in addition the colour of the solution. Virtually all who scored the first mark went on to record that the solution turned colourless on addition of acid.
- (iv) The majority of students identified the gas as sulfur dioxide but some appeared to use paper soaked in aqueous potassium manganate(VII) rather than an acidified solution and so noted that the paper turned brown rather than colourless. A number of students also carried out a further test using paper soaked in acidified dichromate(VI). Although there was not penalty for doing this it is important to stress to candidates that they should not carry out additional tests to those described in the paper unless directed to do so.
- (b) This was very well answered with nearly all students securing the mark
- (c) This again was well answered with many candidates scoring both of these final marks. Students occasionally reasoned that the acid had reacted with the hydrogen peroxide and therefore no acid remained in order to dissolve the precipitate.