

CHEMISTRY

Paper 9791/01
Part A Multiple Choice

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

General comments

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

The mean score for this paper was 30.2. The standard deviation of the scores was 5.2. The score distribution table for this paper was comparable to those of the other three Pre-U papers.

The calculation questions were generally well answered, and candidates showed a good knowledge of organic functional group level chemistry. The last six questions were set on syllabus **sections A4.2 to A4.5** (spectroscopy) and apart from **Question 36** seemed to cause more problems than any other syllabus area examined.

Comments on specific questions

The eight easiest questions, with a proportion correct exceeding 90%, were 2, 11, 12, 13, 16, 26, 30 and 36.

The six most difficult questions, with a proportion correct below 60%, were 4, 7, 20, 21, 35 and 39.

Question 4 proved the most difficult of all, nitrogen, with 3 unpaired and 4 paired electrons being the key.

In **Question 7** many candidates felt the F-F bond was longer than the Cl-Cl bond and gave **C** as the key, perhaps confusing bond length and bond energy.

Question 20 posed an unusual problem to which the majority of candidates felt 4 was the fewest carbon atoms possible. These candidates did not appreciate the chiral carbon atom had to be linked to an aldehyde group, a hydrogen atom, a methyl group and an ethyl group.

In **Question 21** there were two mono, two di and one tri substituted products, over half the candidates thought there to be less than 5.

For **Question 35** 40% of candidates did not realise the F_2 unit was impossible in the mass spectrum of CH_2F_2 .

Butanoic acid was a common wrong answer in **Question 39**, candidates not appreciating that it would give a broad peak from 2500 to 3300 cm^{-1} .

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Paper 9791/02
Part A Written

General comments

This paper showed that candidates coped well with the new content and approach of Pre-U Chemistry and some very pleasing answers were seen. As might be expected, some candidates did not finish the paper and this was noted at the award.

Specific comments

Question 1

This question tested candidates' knowledge of enthalpy changes, and how well they could apply these ideas to comparisons between petrol and other fuels likely to have a significant impact in the future.

- (a) Candidates easily managed this task.
- (b) This calculation was well attempted by many candidates although a number of candidates did not score on this part.
- (c) Most candidates realised this question was just a matter of definition and gained the mark easily. Some candidates omitted this part.
- (d) Most candidates realised that the standard enthalpy of combustion of hydrogen is equal to the standard enthalpy of formation of water.
- (e) A common error was to give the state symbol as (g) for water (forgetting that the equation was to represent the standard enthalpy change). Some candidates gave no state symbols in their equation.
- (f) This part was generally done well. Candidates who set out their working clearly tended to be the most successful.
- (g) This part was generally done well.
- (h) Given the precision of the density data in the question, no more than 3 significant figures were relevant in answers. Many candidates did not appreciate this and gave their answers to 4 significant figures, thus not accessing full marks.
- (i) This part was generally well answered and some clear, concise explanations were seen.

Question 2

While this question was on the new topic of van Arkel diagrams and involved unfamiliar hafnium chemistry, its different parts were still accessible to the candidates sitting the paper.

- (a) This part was answered well and clear calculations were seen in the majority of scripts.
- (b) Candidates were largely successful in plotting the point on the van Arkel triangle, but many classified HfO_2 as a conductor or semiconductor. This was perhaps on seeing that the question referred to computer chips, despite the van Arkel plot indicating that the material is ionic.
- (c) This part was done well.

- (d) Most candidates could apply their knowledge of simple inorganic metal chemistry to these hafnium reactions and therefore scored full marks.

Question 3

This question surveyed bonding, beginning at the very simple level of what ionic bonds are and then advanced into ionic liquids, hydrogen bonding and an H-bonding problem from recent literature.

- (a) This part presented no difficulty to candidates.
- (b) Most candidates were comfortable with dot-cross diagrams though a few had the outer shells of Cs and F overlapping.
- (c) Candidates were expected to emphasise that there is a greater difference in electronegativity between these two elements than any other bonding combination.
- (d) A number of candidates did not know the meaning of *non-volatile*. Answers were often vague with some alluding to reactivity with air.
- (e) Some candidates tried convoluted arguments relating to shape and van der Waals' forces, when the information in the stem of the question was pointing towards to the magnitude of the charges and the distance between the centre of the ions.
- (f) This part was answered well.
- (g) While this part was generally answered well, some candidates only included one end of the relevant dipoles and did not indicate the angle around the H-bonded hydrogen atoms.
- (h) This part was answered well by many of the candidates. Some H-bonds came from the H₂ of NH₂, and therefore only received partial credit.

Question 4

This question examined addition polymerisation in a modern context that included the inorganic analytical chemistry of the polymer's side chains.

- (a) Many candidates drew the repeat unit in skeletal form. It is important that candidates make clear which bonds are dangling by the use of square brackets. Without these, skeletal formulae can be ambiguous and may not gain full marks. Credit was given either for skeletal formulae between square brackets or for displayed formulae where dangling bonds were made clear.
- (b) The correct structure was given by the majority of candidates. Infrequent errors involved not including a C=C double bond in the monomer or including the chlorine atom.
- (c) (i) This part presented few difficulties to candidates.
- (ii) Most candidates realised that oxidation numbers do not change in hydrolysis reactions.
- (iii) The reduction reaction in this part proved testing: many candidates wrote equations involving $C\bar{t}$ ions.
- (iv) Most candidates were evidently familiar with this titrimetric method.
- (v) This part was answered well.
- (vi) This part was answered well.
- (vii) The majority of candidates failed to realise that scaling by a factor of 10 was required and therefore did not gain one of the allowed marks.

Question 5

This question was done very well by many candidates. It tested their knowledge of atomic structure and the Aufbau principle, and if they could apply this knowledge to another subshell at high atomic numbers.

- (a) This part was answered well.
- (b) Most candidates could extend the series of 1, 3, 5, 7 orbitals in the s, p, d, f subshells, respectively.
- (c) This part was answered well.
- (d) This part was answered well.
- (e) This was well answered but an error was to include the 6f orbital.
- (f) Those candidates who were successful in part (e) commonly went on to get this part correct too.

Question 6

This organic question touched on carbon environments and isomerism and went on to consider a 6-step reaction scheme with 5 unknowns. It was generally well answered.

- (a) Most candidates were able to see that the rotation of the central C-C bond would make the two benzene rings symmetrically equivalent with one another.
- (b) Most candidates were able to see the equivalence between the two rings, and the two ortho and meta positions within each ring.
- (c) This was generally well answered. It is important to note that where formulae or oxidation numbers were quoted they had to be correct.
- (d) This part was answered well.
- (e) This part was generally answered well but some candidates confused condensation with dehydration in **reaction 6**.
- (f) Most candidates got the structures of **A**, **B** and **C** correct. The most difficult structure for candidates was structure **D**.

Question 7

This question examined elementary physical and inorganic principles – dipoles, oxidation number, simple covalent VSEPR, hydrolysis and dehydration, bond strengths and activation energy – in the context of nitrogen compounds.

- (a) This part was generally answered correctly though some candidates did not answer it at all.
- (b)(i) Many candidates wrote equations producing hydrogen gas despite being prompted that the oxidation state of hydrogen (from the ammonia) did not change.
 - (ii) This part was answered well.
 - (iii) The dot-cross diagram was done well though a number of candidates called the molecule tetrahedral.
 - (iv) Many referred to the bonding as ionic even though they had drawn a covalent structure in (iii).
- (c)(i) This part was answered well.
 - (ii) Many candidates earned partial credit by writing down the correct formulae without properly balancing the equation.
 - (iii) Most candidates got this part right.

Question 8

This question accounted for most of the practical planning marks allocated to this paper. The chemistry involved (addition across C=C double bonds) was syllabus material, yet the practical was unlikely to have been met by candidates owing to the use of 1,1,1-trichloroethane and the awkwardness of titrating across two phases. Being an unfamiliar practical with lots of detail to assimilate it was a challenging question which was only completed well by the most able candidates.

- (a) This part was answered well.
- (b) A very common error was to write “butaenoic acid” rather than “tetraeneoic acid”.
- (c) A number of candidates did not realise that the answer was 2^n , where n is the number of C=C double bonds.
- (d) Many candidates chose hydrogen bonding, not realising the question was about hydrocarbon chains.
- (e) This part was found more difficult than anticipated.
- (f) This part was answered well.
- (g)(i) A common error was using 127 rather than 254 as the multiplying factor.
 - (ii) A number of candidates did not answer this question.
- (h)(i) This part was answered well.
 - (ii) Common errors were using stearidonic acid rather than the highest molecular weight cervonic acid in the calculation, and also adding Wijs’ reagent with a burette rather than a pipette.
 - (iii) Most candidates were familiar with the iodine-thiosulfate titration technique. Many candidates could have gained extra marks from their answers by making reference to the 30-minute requirement, the use of measuring cylinders for non-limiting reagents, the vigorous shaking of the reaction mixture, and working with 1,1,1-trichloroethane in a fume cupboard.
 - (iv) This part provided an opportunity for the most able candidates to shine, and they usually did, with specific answers detailing how the relevant calculations were to be carried out. General answers about calculating one quantity and then another, without explanation, were not given full credit.

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Paper 9791/03
Part B Written

General comments

This first sitting of the Pre-U Chemistry produced a pleasing spread of results. Some questions were quite consistently well-answered, especially the rate of reaction questions in **2(d)** and the calculations in **3(b)**. Candidates appeared comfortable with all areas of the syllabus tested but as expected the application of concepts in unfamiliar situations was found more challenging by some, notably the final organic identification question.

Comments on specific questions

Question 1

This question tested candidates' knowledge and understanding of pH changes during titration, indicators, dissociation of water and buffer calculations

- (a) What was intended as a straightforward starter question turned out to be much harder than expected for some candidates. A mark was allowed if the overall equation appeared in either **(i)** or **(ii)** or if two correct non-ionic equations were given and, were it not for this, few candidates would have scored here. The separate, sequential nature of the two parts of the process was not recognised by most candidates and many did not seem to know what was meant by an ionic equation.
- (b) All three parts were generally well-answered although some candidates failed to appreciate the need to give a **change** in part **(iii)** and just quoted a single colour.
- (c) The unfamiliar unit of concentration caught out some candidates and prevented access to the final mark but otherwise this was generally well answered.
- (d) The equation in part **(i)** did not cause many problems but, in part **(ii)** many candidates did not appreciate the reason for omitting water from the final expression. Some candidates incorrectly thought that it could be omitted as the value for its concentration was 1 when what was needed was a reference to its being constant as a result of either being in large excess or minimal dissociation.
- (e) The calculation in part **(i)** was often well done although some candidates got no further than a calculation of initial pH of the hydrochloric acid solution. In part **(ii)** the majority of candidates did not recognise that this was a buffer scenario and, again, many candidates settled for an attempt at a calculation of initial pH without any calculation of the effect of adding hydrochloric acid to the mixture.

This question, in particular, illustrated the benefits of adopting a structured and organised approach to problem-solving. In each case there was a need for calculation of initial pH (using an appropriate expression), an adjustment to the amounts present in the stated volume, a calculation of the amount of H^+ being added and, finally a calculation of the changes that this would cause. In the case of part **(ii)** the candidate needed to use the idea of the equilibrium operating in the mixture to calculate the new concentrations of both the CH_3COOH and the CH_3COO^- .

Question 2

This question, being based on halogenoalkanes, allowed a number of ideas to be tested including optical isomerism and reaction rates.

- (a) As in **Question 1** this was intended to be an easy start, focussing on what was expected to be a well-recognised idea, namely that halogenoalkanes react with alkali in two different ways depending mainly on the solvent chosen. Surprisingly, few candidates recognised this fact.
- (b) The first two definitions were well-recognised but the definition of diastereoisomers was less well recognised and in some cases grammatical confusion cost candidates the marks with muddles between not superimposable and not non-superimposable, or contradictions along the lines of optical isomers that are not mirror images. In part **(iv)** most candidates were able to earn both marks but a considerable minority did not represent the second isomer in a conventional manner and so failed to convince the Examiners that they fully understood the concept of mirror-image forms.
- (c) The basic idea of the mechanism was well presented by most candidates in part **(i)** but, as in **(b)(iv)** a failure to represent 3-d structures in the conventional manner led to many candidates failing to persuade the Examiners that they were correctly showing the inversion that occurs during this substitution. Despite the clue given in the stem, some candidates omitted one of both of the prefixes in the full name of the product.
- (d) This rate question was generally very well answered and was clearly a familiar context to the vast majority of candidates. The only occasional weakness was in not fully justifying the conclusions with clear references to the actual data supplied.

Question 3

This question focused on the ideas of entropy and free energy in both qualitative and quantitative contexts. It was clear that most candidates were happier with the quantitative than the qualitative and more practice is needed by many at producing succinct, concise and precise written explanations.

- (a) The chief omission in parts **(i)** and **(ii)** was a reference to disorder. An explanation of entropy change cannot earn both marks if the phrase being explained is repeated as part of the answer. Although many candidates referred to either state changes (or lack of them) or to Δn , few answers properly combined both of these and then went on to state what effect these comparisons had on the degree of disorder.
- (b) The calculations were generally well done although there was inevitably some confusion with units and candidates must remember to be careful to distinguish between the use of $\text{JK}^{-1}\text{mol}^{-1}$ for entropy and kJmol^{-1} (usually) for ΔH and therefore the need to convert J to kJ (or *vice versa*) for ΔG when using the expression $\Delta G = \Delta H - T\Delta S$.
- (c) Most candidates extracted the correct expression from the data sheet and did well in part **(i)** although there were some unsuccessful attempts to use an expression based on partial pressures. The temperature was generally calculated successfully in part **(ii)** except for those candidates who, again, confused the units.
- (d) Most candidates recognised that this was a question about activation energy and gained the available mark.

Question 4

This question about transition metal complexes covered formulae, structure, isomerism, shapes and colour.

- (a) The calculation was generally well done although, once again, a lack of rigour with the structure of answers by some candidates made the working hard to follow and quite a lot of candidates made the mistake of assuming that the empirical formula calculated was also the molecular formula and failed to make use of the RMM to justify the molecular formula. The cis and trans isomers were correctly identified by many candidates although a significant minority offered one tetrahedral and one square planar structure instead.
- (b) The bond angles were generally well known although many candidates had failed to commit suitable examples to memory and charges were often omitted or incorrect.
- (c) The explanation of colour was generally well done and had obviously been learned thoroughly by most candidates. A lack of specific reference to orbitals and their orientations were the commonest reasons for missed marks.

Question 5

This organic question started gently, albeit in a probably unfamiliar context, but part (e) was only well attempted by the strongest candidates. Again, the key to success in such questions is a carefully reasoned and well-structured response that gradually builds to an answer from all the clues given. The mark scheme was structured in such a way that full credit could be earned for the sections of ^1H and ^{13}C NMR even if the structures offered were incorrect – as was frequently the case.

- (a) Most candidates counted correctly although the mark was lost by those who did not give a true molecular formula.
- (b) The bond angles were correctly identified by most candidates.
- (c) These names were not as well recalled as the Examiners had expected but many candidates earned both marks.
- (d) In part (i) most candidates could identify a nucleophile as an electron pair donor but few went on to mention covalent bond formation. In part (ii) despite the clue in the stem of mentioning **addition** polymerisation, many candidates did not recognise that this was polymerisation of an alkene.
- (e) The key to success in identifying the five structures was for candidates to appreciate that the reduction with LiAlH_4 would reduce the nitrile to an amine and the ester to alcohol and carboxylic acid but **not** reduce the C=C double bond. However, the use of hydrogen and a nickel catalyst would reduce the C=C and the nitrile group but not affect the ester link.

Most candidates recognised that the reactions with ethanoyl chloride constituted acylation of $-\text{NH}_2$ or $-\text{OH}$ groups and error carried forward marks were available from incorrect structures of **Q** and **R**.

Discussions of the ^{13}C NMR spectrum of **T** were frequently let down by implying that the peaks were due to bonds rather than due to the C atoms themselves and candidates need to be careful with their phraseology in this type of situation and say, for example, that a peak is due to a C atom in a C=O group rather than just saying that it is due to the C=O bond.

Most candidates recognised the reference to a labile hydrogen in the ^1H spectrum of **U**, although many failed to use the actual phrase. Error carried forward from incorrect structures was only permissible if both $-\text{NH}_2$ and $-\text{OH}$ groups (if both present in the suggested structure) were suggested as being involved.

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Paper 9791/04

Practical

General Comments

Overall this paper revealed a high degree of practical skill among the candidates and a strong ability to record their results and observations in a clear and succinct form. There was no indication from the paper that any problem had arisen in terms of completing the questions within the allotted time and indeed many scripts suggested that perhaps candidates had rushed a little at **Question 1** and would have gained higher marks if they had considered the experiment and the recording of the results a little more before starting the practical work. The weaker areas revealed by the candidates' responses centred on the uncertainty of measurements in part **(a)** and the tests of the organic compounds in part **(c)**.

In relation to the conduct of the exam, it should be stressed how important it is that Centres follow closely the requests made in the Confidential Instructions under the heading 'Responsibilities of the Supervisor during the Examination'.

Comments about specific questions

Question 1

- (a)** Many candidates did not present their results in a suitable table but rather recorded some results in a tabulated form with other pieces of data randomly set out on the page. It is important to stress to candidates that when they read through the instructions for the first time it is a good idea to draw up a table which is then ready to record all the data that the question requires. Virtually every candidate recorded the masses appropriately using the same precision and with the units clearly indicated. When it came to calculating the mass of residue and the mass of water loss, a few candidates became somewhat muddled and by subtracting the wrong pair of masses ended up with these values interchanged. The quality of the experimental work was excellent and almost every candidate scored both available marks.
- (b)** In the main this calculation was well handled with the majority of candidates scoring full marks. Routes to the correct answer varied with a significant number of candidates using the rather more convoluted method of expressing the relative formula mass of the hydrated salt as $120.4 + 18x$ and then solving for x .
- (c)** Answers here were perhaps slightly disappointing. In particular a number of candidates did not realise the need to double the error when considering the uncertainty in the mass of water lost. It was noteworthy that a number of candidates tripled this error arguing that they had recorded three masses, these being the mass of the crucible (a), the mass of the crucible and **FA 1** (b), and the mass of the crucible and the residue (c). They then worked out the mass of **FA 1** ($b - a$) and the mass of the residue ($c - a$) and then used the difference to calculate the mass of water lost, this being, of course, the same as if they had subtracted c from b . Other candidates multiplied the error by the number of readings they had taken as on each occasion they had worked out the mass of water lost.
- (d)** This was reasonably well answered, although some candidates did suggest an improvement without then proceeding to explain why this would lead to a more accurate value of x .

Question 2

- (a) Overall this was very well answered. Almost every script indicated that the candidate had performed the reactions carefully and had noted their observations with care. Occasionally the observations recorded needed to be clearer. For example, on mixing **FA 6** and **FA 2** some candidates referred to a white precipitate that dissolved on shaking, when they needed to explain that the white precipitate was in fact soluble in excess **FA 2**. Also, it is insufficient to say the solution turns white when what is observed is the formation of a white precipitate. A few candidates also tended to use incorrect terminology, for example referring to emulsions rather than the formation of a precipitate. Some candidates also referred to liquids rather than solutions which although not a sufficient error to lose any mark is nevertheless poor practice.
- (b) This was extremely well answered with many candidates scoring all six marks and almost all identifying at least four of the ions correctly.
- (c) Every candidate gave the correct response for testing a nitrate by heating with hydroxide and aluminium foil but only a few candidates realised that a nitrite would give the same result and that consequently it would also be necessary to perform a test for the nitrite ion.

Question 3

- (a) In terms of the experimental procedure candidates undoubtedly found this more challenging than the experiments involved in the earlier two questions. Given that the paper told the candidates which compounds were present, it was surprising that some candidates were content to record results that could not have been given by any of the contenders for **FA 7–9**. The results were nearly always presented very clearly within a single table.
- (b) Again candidates struggled a little here and once again gave answers which simply could not be justified by the observations they had made in part (a). A handful of candidates did acknowledge that their results must have been in error but some others clearly struggled to recall what the appropriate observations should have been.