

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to many of the candidates.

Eleven questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 2, 3, 4, 9, 12, 14, 19, 22, 28, 29** and **35**. Four questions can be said to have been found to be particularly difficult. Less than 25% of candidates chose the correct responses to each of **Questions 6, 7, 34** and **38**.

Comments on Specific Questions

Question 6

12% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 39% of candidates. Candidates needed to calculate that the energy required to form 8S(g) + 16O(g) is $2232 + (8 \times 496) = +6200$ kJ. Drawing an energy cycle, and correctly labelling the enthalpy change

of combustion of S_8 as -2376 kJ, shows that the energy change $8SO_2(g) \rightarrow 8S(g) + 16O(g)$ is $+8576$ kJ. This is sixteen times the S=O bond enthalpy, which is therefore $+536$ kJ mol⁻¹.

Question 7

24% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 33% of candidates. Candidates were expected to calculate the energy transferred to the water, $100 \times 4.18 \times 58 = 24244$ J or 24.2 kJ. This answer had to be divided by 0.025 moles, and given a minus sign since the energy was given out by the burning fuel, to get the final answer, -970 kJ mol⁻¹. The answer **D** was -24.2 kJ, so it seems likely that candidates choosing **D** stopped after calculating the energy transferred to the water.

Question 34

18% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 67% of candidates. For many candidates this question therefore rested on the truth, or otherwise of statement **2**, which is false.

Question 38

24% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 33% of candidates. Candidates needed to find the formula of each diol produced by the initial reduction, and then work out the formula or formulae of all possible dienes produced by dehydration with an excess of concentrated sulfuric acid.

For many candidates this question rested on whether the diol formed from structure **1** would give one, or more than one, structure with the molecular formula C_7H_{10} . If it gives one, the answer is **A**. If it gives more than one, the answer is **C**. The diol has an OH group in the side chain, the resulting dehydration produces a double bond in the side chain. The diol also has an OH group in the ring, two C-C bonds away from the side chain. The dehydration resulting from this OH group produces a double bond in the ring. This double bond can be one C-C bond away from the side chain, or two C-C bonds away from the side chain. There are therefore two possible structures with the molecular formula C_7H_{10} , and the answer is **C**.

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Paper 9701/12
Multiple Choice

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

General Comments

This examination paper provided a suitable challenge to the candidates. There were a large number of pleasing performances, and some excellent ones.

Fifteen questions can be said to have been found to be easier. 60% or more of candidates chose the correct responses to each of **Questions 2, 8, 9, 10, 11, 14, 15, 19, 20, 21, 22, 24, 26, 28, and 32**. Four questions can be said to have been found to be particularly difficult. 30% or less of candidates chose the correct responses to each of **Questions 3, 30, 39 and 40**.

Comments on Specific Questions

Question 3

26% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 36% of candidates. This suggests that the majority of candidates were able to rule out **A** and **B**, presumably using the knowledge that the melting point of sodium is much lower than 420 °C. The question

then required candidates to choose the more significant piece of information. KCl and NaF might both fit the data for **V**. However the data shows that **W** is a liquid at room temperature. HCl is a gas at room temperature, $SiCl_4$ is a liquid, so **W** is $SiCl_4$ and the key is **D**.

Question 30

27% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 28% of candidates. The statistics for this question suggest many candidates guessed their answer. Bond 1 is an amide linkage. Bond 2 is an ester linkage. Both bond 1 and bond 2 will be broken when aspartame is warmed with aqueous alkali, as amide linkages and ester linkages are both hydrolysed by warm aqueous alkali.

Question 39

15% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 42% of candidates. These statistics show that the majority of candidates realised that, on heating with excess concentrated sulfuric acid, structures 1 and 2 produce only one product with molecular formula C_7H_{10} . However most of the candidates who got this far then decided that structure 3 would also produce only one product with molecular formula C_7H_{10} , so they chose **A**. However the OH group on the ring in structure 3 can dehydrate in two ways, either across the bond nearer to the side chain or across the bond further away from the side chain. These two dehydrations give two different products, and the key is **B**.

Question 40

16% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 44% of candidates. This question required candidates to find the products formed by oxidative cleavage of the $C=C$ double bonds in the structures given. All three structures will give CO_2 and the same molecule with two ketone groups and one carboxylic acid group. Therefore the key was **A**.

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Paper 9701/13
Multiple Choice

<i>Question Number</i>	<i>Key</i>	<i>Question Number</i>	<i>Key</i>
1	C	21	C
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8	D	28	B
9	B	29	B
10	B	30	B
11	C	31	C
12	A	32	B
13	A	33	B
14	A	34	D
15	D	35	B
16	D	36	A
17	B	37	C
18	A	38	C
19	A	39	D
20	C	40	B

General Comments

This examination paper proved to be accessible to many of the candidates. There were many pleasing performances, and some really outstanding ones.

Sixteen questions can be said to have been found to be easier. 65% or more of candidates chose the correct responses to each of **Questions 1, 3, 4, 7, 9, 12, 14, 15, 19, 22, 26, 28, 29, 30, 35** and **36**. Four questions can be said to have been found to be particularly difficult. Less than 40% of candidates chose the correct responses to each of **Questions 5, 34, 37, and 38**.

Comments on Specific Questions

Question 6

34% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 30% of candidates. Candidates needed to calculate that the energy required to form 8S(g) + 16O(g) is $2232 + (8 \times 496) = +6200$ kJ. Drawing an energy cycle, and correctly labelling the enthalpy change

of combustion of S_8 as -2376 kJ, shows that the energy change $8SO_2(g) \rightarrow 8S(g) + 16O(g)$ is $+8576$ kJ. This is sixteen times the S=O bond enthalpy, which is therefore $+536$ kJ mol⁻¹.

Question 34

27% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 58% of candidates. For many candidates this question therefore rested on the truth, or otherwise of statement **2**, which is false.

Question 37

39% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 42% of candidates. It is possible that candidates who chose **D** had missed the key point in the question, i.e. that they were looking for reagents that react differently with the two acids.

Question 38

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 34% of candidates. Candidates needed to find the formula of each diol produced by the initial reduction, and then work out the formula or formulae of all possible dienes produced by dehydration with an excess of concentrated sulfuric acid.

For many candidates this question rested on whether the diol formed from structure **1** would give one, or more than one, structure with the molecular formula C_7H_{10} . If it gives one, the answer is **A**. If it gives more than one, the answer is **C**. The diol has an OH group in the side chain, the resulting dehydration produces a double bond in the side chain. The diol also has an OH group in the ring, two C-C bonds away from the side chain. The dehydration resulting from this OH group produces a double bond in the ring. This double bond can be one C-C bond away from the side chain, or two C-C bonds away from the side chain. There are therefore two possible structures with the molecular formula C_7H_{10} , and the key is **C**.

CHEMISTRY

<p>Paper 9701/21 AS Structured Questions</p>
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Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required: the accurate use of chemical terminology is welcomed, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument, and it is advised that only a narrow range of vocabulary be permitted when assessing understanding.

Candidates ought to be clear about the difference between intermolecular and intramolecular forces, and to recall concisely the details of structure and bonding in generic states of substances that show covalent, ionic and metallic bonding.

Candidates should look to practise applying their knowledge of organic chemistry, as questions based thereon frequently highlight unfamiliarity.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was similar to last year with good recall of material shown across the paper. Scripts were generally clear and well presented; as a general point of presentation, it ought to be noted that it is difficult for examiners to read scripts where answers written in pencil have been overlaid with ink and not rubbed out.

Comments on Specific Questions

Question 1

- (a) Candidates did not fully understand the nature of metallic bonding. 'Surrounded by delocalised electrons' or similar phrases were most often present but the regular arrangement/lattice structure of the positive ions was rarely mentioned.
- (b)(i) The word 'conductor' appeared regularly in answers, but with no indication of whether it was associated with 'electrical' or 'heat'. Candidates also referenced high melting point and boiling point but with no qualification.
- (ii) This question required reference to giant covalent, but candidates produced many different responses. 'Giant molecular' could not be credited, while 'macromolecular' was accepted.
- (iii) Similarly to answers to (b)(i), 'insulator' appeared regularly, but with no qualification.
- (c)(i) Those candidates who recognised that this compound was simple and not ionic/metallic generally appreciated that the intermolecular forces were weak.
- (ii) Most candidates gained credit for this calculation, though the errors of inverted fractions, use of Z rather than A_r , flipped ratios and use of Cl_2 rather than Cl were often seen.
- (iii) Some candidates did not convert p and V (and even T) correctly. A few candidates did not respond to the requirement for the answer to be provided to three significant figures.

- (iv) Candidates nearly always gave the correct molecular formula, though this could not be credited without a correct answer to (c)(iii).

Question 2

- (a) (i) This question was quite well answered, though common errors were to refer to 'energy required' or 'energy absorbed/needed', rather than 'energy change'.
- (ii) Once sulfur and oxygen were correctly identified, balancing the equation was often well done, though the requirement for state symbols was often missed.
- (b) (i) Candidates occasionally used incorrect bond energies, or the wrong stoichiometry (e.g. $3 \times \text{N—H}$ bond energy), though many correct answers were given.
- (ii) There were many correct answers to this recall question.
- (iii) Most candidates were awarded partial credit but many omitted rate and yield from their answer.
- (c) (i) This was well attempted by most candidates.
- (ii) This was not well answered. Candidates were generally clear on the definition of an acid and base, but were less able to link this to NH_3 and H_3PO_4 . Quite a few answers referred to conjugate acids and bases instead.
- (d) (i) Candidates generally made a good attempt at this question, however practice is required to ensure all marking points are covered. 'Eutrophication' or equivalent phrases were most frequently awarded credit, while 'washed/seeped into rivers' was often overlooked. The lack of oxygen was attributed to a variety of factors – but not always 'used up by the bacteria' or through mention of a lack of sunlight leading to less/no photosynthesis.
- (ii) Acid rain often appeared in candidates' answers, but the associated equation(s) were less well attempted.

Question 3

- (a) (i) Many definitions of structural isomerism were not sufficiently detailed for the award of credit

Candidates' knowledge of chiral centres seemed secure, although they are reminded of the need to be precise in their use of chemical terminology, i.e. four different (groups of) atoms, not molecules/compounds, etc.

- (ii) Despite their answers to (a)(i), candidates seemed not to recognise (the requirement for) a chiral centre. Credit was available for correct names of the wrong C₇ alkanes, but often names were also incorrect.

- (b) (i) There were many correct answers to this part.

- (ii) Many excellent answers were given to this question, though commonly the solid pollutant was overlooked: equations appeared mainly with CO. Candidates should know that H₂ is not an acceptable product of incomplete combustion.

- (iii) Candidates need to be more explicit in their answer to these kind of questions: quite a few answers were given mentioning just 'air pollution' and 'ozone layer'.

- (c) (i) There were many correct answers to this part.

- (ii) Candidates were often able to score well on this question, though for many answers credit could not be awarded as a result of contradictory answers to each stage of the mechanism. The initiation and termination stages were the best attempted; the propagation steps were often incorrect.

Candidates are asked to retain a single convention throughout for representing a free radical: all relevant species should be labelled with or without a lone electron (e.g. C₇H₁₅[•] or C₇H₁₅), but the representation should be consistent in all equations given.

Question 4

- (a) (i) HCl was the most frequent reagent and the equation was easily written as a result. Choice of SOCl₂ or PCl₅ was widespread, but credit for the relevant equation was less often awarded. Candidates are reminded of the need for careful presentation, making sure clearly to write (e.g.) the numerals 2, 3 and 5 differently.

- (ii) NaOH (and KOH) were frequently correctly given, as was the heating condition, but many answers crucially missed making mention of aqueous or (aq) reagents (as opposed to alcoholic conditions).

- (b) (i) This question was generally not well answered.

- (ii) This observation was given correctly by many candidates; some neglected to specify the colour of the precipitate.

- (iii) Answers to this question varied greatly in quality and content. It was clear that many candidates were unfamiliar with the definition of an ionic equation, and were unpractised in writing them. Even on otherwise correct equations, state symbols were often incorrect, thus credit could not be awarded.

- (c) (i) This question was better answered than (b)(i), but still elicited many different answers – ethanol and ethanoic acid being the most frequent.

- (ii) Many candidates were awarded at least partial credit here. Reference to distillation in order to isolate the aldehyde was the most frequently awarded marking point, whilst the link to prevention of further oxidation was rarely seen. A comparison of boiling points was also absent, though hydrogen bonding scored frequently.

CHEMISTRY

Paper 9701/22
Structured Questions AS Core

Key Messages

Candidates should be reminded to read questions carefully and check their answers thoroughly.

Clear distinctions are needed when using subject-specific terms; especially with regard to the key distinctions between different bonding and intermolecular forces.

Candidates should be reminded that all working in calculations should be shown to ensure that due credit can be awarded.

Candidates should avoid offering unnecessary multiple answers as sometimes an otherwise correct first attempt can be invalidated.

Candidates must avoid simply repeating the question when asked for an explanation.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. In **Question 1** there was much confusion between the various types of bonding and intermolecular forces; with covalent bond strength often thought to be related to melting and boiling points of molecular substances.

Calculations were generally well done. Organic reactions need more rigorous study for many candidates.

Comments on Specific Questions

Question 1

- (a) The table of data relating to some isotopes was generally well completed. There was some confusion with some candidates using relative atomic mass data from their Periodic Tables instead of the mass (nucleon) number data given in the table.

Candidates should be secure of the distinction between the mass (nucleon) number, which is always an integer and identifies the total number of nucleons in a specific atom, and the relative atomic/isotopic mass, which is a value representing the mass of an atom relative to $1/12^{\text{th}}$ the mass of an atom of ^{12}C ; it is usually written to several decimal places.

- (b)(i) Many candidates needed to be more specific in their references, often mentioning that it was the attraction of an *atom* (or *nucleus*) for the *bond electrons*.
- (ii) Most candidates were able to identify the type of bonding here as covalent but few then actually explained this type of bonding correctly: although there were many references to shared electrons, few answers were specific about electron *pair(s)*.
- (iii) Most candidates identified ionic bonding correctly but, in many cases, went on to describe how ions form (by electron transfer) rather than actually describing the bond formed – i.e. the attraction between oppositely charged ions
- (c) This sequence of questions revealed some significant confusion with regard to the differences between different types of bonding, structure and intermolecular forces.

One problem arises from the different uses of the phrase 'van der Waals' forces' in different books and online resources. Candidates must be clear that, in the 9701 syllabus, the phrase 'van der Waals' forces' is used to refer collectively to both instantaneous dipole-induced dipole forces (which are particularly significant between non-polar molecules and whose strength depends primarily on the number of electrons in a molecule) and to permanent dipole-permanent dipole forces (such as those between polar molecules e.g. HCl and molecules containing a carbonyl-group). The third type of intermolecular force is hydrogen bonding which can only occur between a $\text{H}^{\delta+}$ on one molecule and a lone pair of electrons on certain atoms on another molecule e.g. between molecules of water, ammonia or hydrogen fluoride.

Some candidates did not read the stem of the question, in which they were told that all the molecules referenced have the same number of electrons and so incorrectly tried to explain some of the differences in terms of differing numbers of electrons.

In (i) it was essential for candidates to state that the *strength* of the intermolecular forces is the same and not just that the intermolecular forces are the same. After all, the intermolecular forces in fluorine and iodine are the same (i.e. instantaneous dipole-induced dipole in both cases), but the boiling points are very different. In the second part of the answer many candidates implied that they were referring to the energy needed to break *bonds* and this phrase should be avoided as it implies that candidates are referring to the covalent bonds in a molecule rather than to the (weak) forces between the molecules.

In (ii) the key distinction that needed making was that HCl is polar whilst F_2 is not. Many candidates did not make this key statement but instead referred to the different types of intermolecular forces. This is a valid approach but led to problems with the use of the term 'van der Waals' forces'. The intermolecular forces in both cases are van der Waals' forces – permanent dipole forces in HCl and induced dipole forces in F_2 .

Many candidates also, incorrectly, believed that there are hydrogen bonds between molecules of HCl .

In (iii) most candidates recognised the presence of hydrogen bonds between molecules but then often referred to covalent bonds which could not be awarded credit.

Candidates should remember that the only context in which it is relevant to describe covalent bond strength when explaining melting points is in giant covalent structures such as diamond and silicon dioxide.

Question 2

- (a) Many candidates gave correct reference to standard conditions but very few candidates referred to 'the amounts of reactants *as shown in the equation*', instead referring to one mole of reactants and/or products.
- (b) (i) The calculation was generally done well although a significant minority of candidates included the mass of solid instead of just the mass of 'water' and some added 273 to their temperature difference.
- (ii) This was well answered.
- (iii) A number of candidates either gave no sign or mistakenly gave a positive sign here.
- (iv) Many candidates did not produce a suitable energy cycle.
- (v) Candidates should ensure they have fully read the question as here, again, the sign was often omitted.

Question 3

- (a) (i) Most candidates correctly filled in the formulae. Two exceptions were the oxides of phosphorus which were not well known, and SO_3 was often incorrectly given rather than SO_2 . The use of P_2O_3

and P_2O_5 were allowed here but candidates should note that these are actually empirical formulae and that P_4O_6 and P_4O_{10} are the correct formulae of these oxides.

- (ii) This was generally well answered although candidates should ensure that equations are balanced as $2Na + O_2 \rightarrow Na_2O$ was frequently seen.
- (b)(i) A surprising number of candidates did not include all 5 elements in this table with many omitting either S or P from the 'acidic' section and either Na or Mg from the 'basic' section.
 - (ii) This question was well answered.
 - (iii) Candidates were not secure in their knowledge of these reactions of aluminium oxide.
- (c) SO_2 was frequently incorrectly suggested as the impurity rather than sulfur.

Question 4

- (a)(i) The name of the mechanism was well known.
 - (ii) This question was well answered.
 - (iii) Some good structure drawing was seen but many candidates should be made aware of the appropriate convention as shown in the syllabus.
 - (iv) The name of the mechanism was well known.
 - (v) The structures were generally drawn well but names were often incomplete.
 - (vi) The name was often correct but candidates found it tricky to explain the lack of isomerism. Candidates should ensure they are referring to the fact that both groups on one of the carbon atoms in the double bond are the same.
- (b)(i) This reagent was well known.
 - (ii) Few candidates suggested the appropriate reagent.
 - (iii) Candidates found this question difficult, suggesting that amide formation was not well known.
 - (iv) Reduction was usually correctly suggested but most candidates then incorrectly suggested $NaBH_4$ as the reagent.
 - (v) This answer was well known.
 - (vi) Many candidates found representation of the mechanism difficult. Careful positioning of curly arrows is very important and candidates should remember that arrows must be shown starting from a bond or a lone pair and going to an atom. To make this clear, it is suggested that candidates ensure that the arrow touches the line representing the bond being broken.
 - (vii) The name of the mechanism was well known.
 - (viii) This question was not well answered. Rather than simply state 'Markovnikov's Rule' as their complete answer, candidates should describe how this rule explains the products of the reaction.

A proper explanation of the reasoning must refer to the relative stabilities of the primary and secondary intermediate carbocations in terms of the inductive effects of the attached alkyl groups.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required: the accurate use of chemical terminology is welcomed, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument, and it is advised that only a narrow range of vocabulary be permitted when assessing understanding.

Candidates ought to be clear about the difference between intermolecular and intramolecular forces, and to recall concisely the details of structure and bonding in generic states of substances that show covalent, ionic and metallic bonding.

Candidates should look to practise applying their knowledge of organic chemistry, as questions based thereon frequently highlight unfamiliarity.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was similar to last year with good recall of material shown across the paper. Scripts were generally clear and well presented; as a general point of presentation, it ought to be noted that it is difficult for examiners to read scripts where answers written in pencil have been overlaid with ink and not rubbed out.

Comments on Specific Questions

Question 1

- (a) Candidates did not fully understand the nature of metallic bonding. 'Surrounded by delocalised electrons' or similar phrases were most often present but the regular arrangement/lattice structure of the positive ions was rarely mentioned.
- (b)(i) The word 'conductor' appeared regularly in answers, but with no indication of whether it was associated with 'electrical' or 'heat'. Candidates also referenced high melting point and boiling point but with no qualification.
- (ii) This question required reference to giant covalent, but candidates produced many different responses. 'Giant molecular' could not be credited, while 'macromolecular' was accepted.
- (iii) Similarly to answers to (b)(i), 'insulator' appeared regularly, but with no qualification.
- (c)(i) Those candidates who recognised that this compound was simple and not ionic/metallic generally appreciated that the intermolecular forces were weak.
- (ii) Most candidates gained credit for this calculation, though the errors of inverted fractions, use of Z rather than A_r , flipped ratios and use of Cl_2 rather than Cl were often seen.
- (iii) Some candidates did not convert p and V (and even T) correctly. A few candidates did not respond to the requirement for the answer to be provided to three significant figures.

- (iv) Candidates nearly always gave the correct molecular formula, though this could not be credited without a correct answer to (c)(iii).

Question 2

- (a) (i) This question was quite well answered, though common errors were to refer to 'energy required' or 'energy absorbed/needed', rather than 'energy change'.
- (ii) Once sulfur and oxygen were correctly identified, balancing the equation was often well done, though the requirement for state symbols was often missed.
- (b) (i) Candidates occasionally used incorrect bond energies, or the wrong stoichiometry (e.g. $3 \times \text{N—H}$ bond energy), though many correct answers were given.
- (ii) There were many correct answers to this recall question.
- (iii) Most candidates were awarded partial credit but many omitted rate and yield from their answer.
- (c) (i) This was well attempted by most candidates.
- (ii) This was not well answered. Candidates were generally clear on the definition of an acid and base, but were less able to link this to NH_3 and H_3PO_4 . Quite a few answers referred to conjugate acids and bases instead.
- (d) (i) Candidates generally made a good attempt at this question, however practice is required to ensure all marking points are covered. 'Eutrophication' or equivalent phrases were most frequently awarded credit, while 'washed/seeped into rivers' was often overlooked. The lack of oxygen was attributed to a variety of factors – but not always 'used up by the bacteria' or through mention of a lack of sunlight leading to less/no photosynthesis.
- (ii) Acid rain often appeared in candidates' answers, but the associated equation(s) were less well attempted.

Question 3

- (a) (i) Many definitions of structural isomerism were not sufficiently detailed for the award of credit

Candidates' knowledge of chiral centres seemed secure, although they are reminded of the need to be precise in their use of chemical terminology, i.e. four different (groups of) atoms, not molecules/compounds, etc.

- (ii) Despite their answers to (a)(i), candidates seemed not to recognise (the requirement for) a chiral centre. Credit was available for correct names of the wrong C₇ alkanes, but often names were also incorrect.

- (b) (i) There were many correct answers to this part.

- (ii) Many excellent answers were given to this question, though commonly the solid pollutant was overlooked: equations appeared mainly with CO. Candidates should know that H₂ is not an acceptable product of incomplete combustion.

- (iii) Candidates need to be more explicit in their answer to these kind of questions: quite a few answers were given mentioning just 'air pollution' and 'ozone layer'.

- (c) (i) There were many correct answers to this part.

- (ii) Candidates were often able to score well on this question, though for many answers credit could not be awarded as a result of contradictory answers to each stage of the mechanism. The initiation and termination stages were the best attempted; the propagation steps were often incorrect.

Candidates are asked to retain a single convention throughout for representing a free radical: all relevant species should be labelled with or without a lone electron (e.g. C₇H₁₅[•] or C₇H₁₅), but the representation should be consistent in all equations given.

Question 4

- (a) (i) HCl was the most frequent reagent and the equation was easily written as a result. Choice of SOCl₂ or PCl₅ was widespread, but credit for the relevant equation was less often awarded. Candidates are reminded of the need for careful presentation, making sure clearly to write (e.g.) the numerals 2, 3 and 5 differently.

- (ii) NaOH (and KOH) were frequently correctly given, as was the heating condition, but many answers crucially missed making mention of aqueous or (aq) reagents (as opposed to alcoholic conditions).

- (b) (i) This question was generally not well answered.

- (ii) This observation was given correctly by many candidates; some neglected to specify the colour of the precipitate.

- (iii) Answers to this question varied greatly in quality and content. It was clear that many candidates were unfamiliar with the definition of an ionic equation, and were unpractised in writing them. Even on otherwise correct equations, state symbols were often incorrect, thus credit could not be awarded.

- (c) (i) This question was better answered than (b)(i), but still elicited many different answers – ethanol and ethanoic acid being the most frequent.

- (ii) Many candidates were awarded at least partial credit here. Reference to distillation in order to isolate the aldehyde was the most frequently awarded marking point, whilst the link to prevention of further oxidation was rarely seen. A comparison of boiling points was also absent, though hydrogen bonding scored frequently.

CHEMISTRY

Paper 9701/31

Advanced Practical Skills 1

Key Messages

- Figures used in deductions must come from the practical results obtained rather than being based on theoretical values.
- Candidates should take care when rounding values and quoting to a specific number of significant figures.
- When completing equations these must be balanced and have correct state symbols if required.
- Answers must be precise and relate to the question as set.

General Comments

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Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Very few candidates were unable to complete the practical work, and most were able to gain credit both for accuracy and in the calculation. This question was answered well by a large majority of candidates.

- (a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. If the readings for the rough titration are incorporated in the accurate titration table then they must be labelled as 'rough'. There are still many candidates who do not record accurate burette readings to 0.05 cm^3 or jeopardise the credit available for concordant titres by carrying out further titrations which are more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3 .
- (b) The majority of candidates calculated a suitable value of the volume of **FA 4** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation, use only values that have a total spread of 0.20 cm^3 and record their answers correct to 2 decimal places.
- (c) The majority of candidates were familiar with the relevant formula/stoichiometric considerations and were able to gain credit for (i) and (ii) as well as that for (iii). However in (iv) only a few candidates calculated the number of moles of iodine correctly. Most realised that it was necessary to use (ii) and (iii) but, in spite of 2.00 being shown in bold font in the question, very few included this factor successfully in their calculation. If an incorrect answer was given in (iv) credit was still available for

choosing the equation in **(v)** that corresponded to this. In **(vi)**, since the question stated that the iodide ion had been oxidised, it was necessary to give a precise description of what had happened to the ion. This could be based on the increase in oxidation state or the loss, by the ion, of an electron.

- (d)(i)** Although many candidates recognised that only one reading is taken when using a pipette so that the error is $\pm 0.06 \text{ cm}^3$, a large number doubled this in their calculation.
- (ii)** Most candidates who gave acceptable answers, concentrated on the fact that all pipettes with which they were familiar were graduated only to deliver 20.0 cm^3 . An alternative correct answer was that the **FA 3** was in excess and therefore the actual precise volume added was irrelevant.

Question 2

- (a)** Most candidates carried out the practical exercise competently since their change in measured rates followed the expected order when the volumes were altered. The instructions asked, in bold, that times should be measured to the nearest second but, in spite of this, a large number of candidates quoted times to a greater degree of accuracy. Most candidates gained at least partial credit for accuracy which was assessed by looking at the increase of the time as **FA 5** was diluted.
- (b)(i)** Most candidates correctly calculated the rates using the expression given with only a few incorrectly rounding the answer or giving it to an inappropriate number of significant figures. Most also gave the correct unit (s^{-1}) with only a few giving s or including moles in some way.
- (ii)** It was not generally recognised that the total volume of solution was 70 cm^3 and so many candidates calculated this incorrectly.
- (iii)** This is an example in which the stated conclusion must follow the calculated data. If, for example, the values of rate in **(b)(i)** increase from Experiment 1 to Experiment 2 whilst the initial concentration of acid decreases, it cannot be correct to conclude that rate increases as concentration increases.
- (iv)** Since the question referred to the effect on **time** it was not acceptable to refer only to the effect on **rate**. To gain credit, candidates had to refer specifically to sulfuric acid producing a greater concentration of H^+ due to it being diprotic. It is not true to state, as many candidates did, that either of the two acids is stronger.
- (v)** This part was answered correctly by very few candidates. Most answers were based on an increase in surface area if a larger capacity beaker were used rather than the fact that the smaller depth of solution present meant that it would take longer for sufficient sulfur to form to obscure the insert.

Question 3

There was evidence that candidates were generally using the Qualitative Analysis Notes but errors/imprecision in the observations led to some incorrect conclusions.

- (a) Although nearly all candidates observed the formation of a white precipitate in both (i) and (ii) many also reported that both the precipitates remained when dilute hydrochloric acid was added. In (iii) a significant number observed that a gas was formed and some reported that the gas was acidic by using litmus paper. Very few identified the gas as sulfur dioxide. In (iv) a minority reported that the solution went green but more observed the formation of the colourless solution when sulfuric acid was added. In view of the conflicting evidence seen by many in (i) and (ii) it was perhaps not surprising that few candidates correctly identified the anion as being sulfite in (v). Credit was however given for candidates who stated that sulfate was present if they used the evidence of the insolubility of the precipitate formed with Ba^{2+} in hydrochloric acid. This erroneous conclusion did make the equation in (vi) difficult.
- (b) (i) Evidence that most candidates do use the Qualitative Analysis Notes included the use of the precise description of manganese(II) hydroxide. Most of the observations in the table were correct although the addition of aqueous ammonia to $\text{Ca}^{2+}(\text{aq})$ and $\text{Mg}^{2+}(\text{aq})$ did cause some problems.
- (ii) Most candidates interpreted their evidence correctly to gain at least partial credit for the identification of the cations present.
- (iii) Very few correct equations were seen. Many candidates wrote molecular, rather than ionic, equations and even more, who did write ionic equations, did not balance the number of OH^- ions needed.
- (iv) Very few candidates realised that increasing the concentration was the most effective way of making the appearance of a precipitate more noticeable. The most common answer seen was based on increasing the light level or using a dark coloured background.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Figures used in calculations or deductions must come from the practical results obtained rather than theoretical values.
- Candidates should take care when rounding values.
- When completing equations these must be balanced and have correct state symbols if required.
- The description of chemicals given in the paper may not be the same as in the Confidential Instructions for reasons of cost, availability or safety. Candidates must use the information given in the paper.

General Comments

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Comments on Specific Questions

Question 1

Very few candidates were unable to complete the practical work, and most were able to gain credit both for accuracy and in the calculation. This question was answered well by a large majority of candidates.

- (a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. There is still a minority of candidates who do not record accurate burette readings to 0.05 cm^3 or jeopardise the credit available for concordant titres by carrying out further titrations which are more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3 .
- (b) The majority of candidates calculated a suitable value of the volume of **FA 2** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to 2 decimal places in line with the burette readings.
- (c) Most candidates gained credit in (i). Slightly fewer gained credit for (ii) as some did not note that the stoichiometric ratios led to the same answer as (i). A majority of candidates gained at least partial credit in (iii) but many errors in scaling were seen and some candidates confused the titre volume with the 26.2 g dm^{-3} value given for the concentration. Lack of scaling in (iii) led to very large values for the M_r but those continuing the steps of the calculation correctly in (iv) were given full credit even though no comment about the unusual value was proffered. Errors included some candidates not using the A_r values from the Periodic Table, dividing by 159.6 instead of subtracting and not expressing the final answer as an integer. Some candidates assumed a value for x then

used this to work backwards, and give answers for (iii) and (iv) without use of experimental data. This could not be awarded credit.

Question 2

Almost all candidates attempted all parts of this question though those involving errors and improvements were omitted by some.

- (a) Candidates are advised to read the instructions in the question carefully as some did not draw up the table for their results before starting the practical work. This led to omission of data and confusion between the masses of **FA 4**, the residue and the water lost. A few misinterpreted the instructions and carried out three separate experiments using fresh samples of **FA 4** each time. Others ignored the instruction to reheat the solid and this affected the credit awarded for accuracy. However, a substantial proportion of candidates heated to constant mass and gained at least partial credit for accuracy.
- (b) The majority of candidates answered (i) correctly. However, many either tried to use their own results or omitted an answer to (ii). A significant number of candidates mistakenly thought the answer to (iii) involved a subtraction rather than a ratio.
- (c) Few candidates gave clear correct answers. Many argued about more water being lost but without focusing on the percentage error.
- (d) Some candidates correctly reasoned that as the impurity decomposed the sample would become purer but did not link this with their answer to (b)(iii) as directed.

Question 3

Almost all candidates attempted all parts of this question.

- (a) Candidates should be aware that 'solutions' can never be described as white. While almost all candidates gained credit for effervescence on adding aqueous sodium carbonate to **FA 6** and **FA 7**, very few concluded the solutions contained the H^+ ion in (ii). By far the most common answer was CO_3^{2-} which would not have explained the recorded observations. Few candidates gained credit for (iii) and common incorrect responses were SO_4^{2-} and, contrary to the information given in the question, OH^- . Very few candidates gained credit for (iv) with even some of those using Cu^{2+} and CO_3^{2-} giving incorrect state symbols or including 'spectator' ions.
- (b) When candidates have been informed that the ions are listed in the Qualitative Analysis Notes they should use the help given to word observations correctly: there were many observations seen in (i) that did not accord with the Notes. However, a majority of candidates recorded effervescence on adding hydrogen peroxide. Candidates should be aware that a glowing splint may reignite vigorously but that a conclusion of 'hydrogen' can only come from testing with a lighted splint. Most candidates correctly recorded effervescence in the first part of (ii). As acid was added to the residue a larger volume of alkali needed to be added to the solution formed than is normally used. It was clear from the observations that not all candidates had realised this and some did not note the effect of adding excess. Part (iii) was relatively well answered though some concluded Fe^{2+} from the brown precipitate in (i). Candidates need to practise qualitative analysis questions so they are aware of the subtle differences in colour and solubility of precipitates formed on adding standard reagents. Many correctly identified CO_3^{2-} in (iv). Only a minority gained credit for (v), usually for stating the addition of hydrogen peroxide produced a redox reaction. Those answering with 'oxidation', 'reduction' or 'decomposition' needed to specify to which ion or compound the term referred.

CHEMISTRY

Paper 9701/34

Advanced Practical Skills 2

Key Messages

- Figures used in calculations or deductions must come from the practical results obtained rather than use of theoretical values.
- Candidates should take care when rounding values.
- When completing equations these must be balanced and have correct state symbols if required.
- The description of chemicals given in the paper may not be the same as in the Confidential Instructions for reasons of cost, availability or safety. Candidates must use the information given in the paper.

General Comments

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Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Very few candidates were unable to complete the practical work, and most were able to gain credit both for accuracy and in the calculation. This question was answered well by a large majority of candidates.

- (a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. If the readings for the rough titration are incorporated in the accurate titration table then they must be labelled as 'rough'. There are still many candidates who do not record accurate burette readings to 0.05 cm^3 or jeopardise the credit available for concordant titres by carrying out further titrations which are more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3 .
- (b) The majority of candidates calculated a suitable value of the volume of **FB 2** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to 2 decimal places in line with burette readings.
- (c) The vast majority of candidates gained credit in (i) though slightly fewer realised it should be the same answer in (ii). Many did not use the correct expression in (iii) with a relatively common error being the use of the concentration and volume of **FB 1** and a factor of 250/25 giving an answer of 0.5 mol. Although most answered (iv) correctly many of those with a larger number for (iii) subtracted the wrong way round in (v). Few candidates were able to balance the equation or provide the correct state symbols. The common errors were the omission of '2' before HCl , (l)

instead of (aq) for HCl and (s) instead of (aq) for MgCl_2 . A greater number realised the moles of magnesium required would be half the moles of hydrochloric acid.

- (d) The majority of candidates were able to gain credit in (i) though a relatively common error was that the mixture stopped bubbling or stopped reacting. In (ii) some candidates provided suitable calculations to show that the magnesium would be in excess. Many candidates mistakenly suggested that the A_r would be too high if a higher mass was used.

Question 2

This question was generally well answered. Very few omitted any of the sections.

- (a) Although the majority of candidates set their results out clearly there are still some who refer to 'mass' as 'weight'. A significant minority transposed the mass loss and the mass of residue or did not record these masses. The practical exercise was clearly within the capabilities of most candidates and many scored full credit for accuracy.
- (b) Parts (i) and (ii) were answered well by the majority of candidates. The most common errors were incorrect rounding of answers or incorrect use of significant figures. Slightly fewer candidates gained credit in (iii). The errors were either the use of the mass of hydrated magnesium sulfate or the manufacture of figures to give an answer close to 24.3 in (iv). Those giving the correct answer in (iii) generally also gained credit in (iv) though a few used 32 instead of 32.1 in calculating the M_r of SO_4^{2-} .
- (c) Many answers needed more precise detail and so did not receive credit. A common error in (i) was to state further heating was needed without reference to obtaining constant mass. Only a few candidates appreciated the risk of rehydration in (ii). Common errors were to 'avoid contact with air' and 'to prevent any evaporation of water from the crucible'.

Question 3

Few candidates carried out tests on gases evolved. A significant minority ignored the instruction to give the full name or formula of any reagent selected for a test.

- (a) The majority of candidates answered this section well, with full credit being awarded frequently, although a few omitted it. One relatively common error was to write the reagent for the sulfate test as Ba^{2+} instead of giving the correct formula of the compound used. Some reported a white precipitate for this test and others added sulfuric acid after adding the aqueous barium compound. A significant minority omitted the conclusion or did not report the absence of sulfate ions.
- (b) The large space allowed on the question paper for (i) was designed to encourage candidates to supply answers covering several marking points. Most candidates were not precise or detailed enough in reporting everything they saw. Though many correctly recorded melting, effervescence and some change in colour, it would appear that not all the candidates heated **FB 6** strongly enough for the decomposition to be complete. Very few recorded a positive test for oxygen and some only tested any gas given off with red litmus and not with blue. Some called the final solid a 'precipitate' which was incorrect.

In (ii) a significant number of candidates reported a white precipitate in the first test (with aqueous silver nitrate). It is possible that the distilled water used by candidates to dissolve the remaining **FB 6** was not as pure as anticipated but even so any precipitate should only have been slight or faint. Candidates should be aware that 'no visible reaction' can be a useful observation when deducing identities of compounds. While the majority correctly reported white precipitates with aqueous ammonia and aqueous sodium hydroxide fewer found the precipitates to be soluble in excess of the two reagents. A substantial number of candidates reported red litmus turning blue when the solution of **FB 6** was heated with aqueous sodium hydroxide. Candidates should take care to test any gas evolved and not allow the litmus paper to touch the side of the boiling tube which may have alkaline solution on it. However, many were able to detect ammonia in the final test though it was apparent from (iii) that not all candidates realised they had carried out the

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Devarda's test for a nitrite or nitrate. A substantial minority of candidates achieved sufficient correct observations to identify **FB 6** although not all were able to write the formula correctly.

CHEMISTRY

Paper 9701/35

Advanced Practical Skills 1

Key Messages

- Figures used in deductions must come from the practical results obtained rather than being based on theoretical values.
- Candidates should take care when rounding values and quoting to a specific number of significant figures.
- When completing equations these must be balanced and have correct state symbols if required.
- Answers must be precise and relate to the question as set.

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- (b) The majority of candidates calculated a suitable value of the volume of **FA 4** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation, use only values that have a total spread of 0.20 cm^3 and record their answers correct to 2 decimal places.
- (c) The majority of candidates were familiar with the relevant formula/stoichiometric considerations and were able to gain credit for (i) and (ii) as well as that for (iii). However in (iv) only a few candidates calculated the number of moles of iodine correctly. Most realised that it was necessary to use (ii) and (iii) but, in spite of 2.00 being shown in bold font in the question, very few included this factor successfully in their calculation. If an incorrect answer was given in (iv) credit was still available for

choosing the equation in **(v)** that corresponded to this. In **(vi)**, since the question stated that the iodide ion had been oxidised, it was necessary to give a precise description of what had happened to the ion. This could be based on the increase in oxidation state or the loss, by the ion, of an electron.

- (d)(i)** Although many candidates recognised that only one reading is taken when using a pipette so that the error is $\pm 0.06 \text{ cm}^3$, a large number doubled this in their calculation.
- (ii)** Most candidates who gave acceptable answers, concentrated on the fact that all pipettes with which they were familiar were graduated only to deliver 20.0 cm^3 . An alternative correct answer was that the **FA 3** was in excess and therefore the actual precise volume added was irrelevant.

Question 2

- (a)** Most candidates carried out the practical exercise competently since their change in measured rates followed the expected order when the volumes were altered. The instructions asked, in bold, that times should be measured to the nearest second but, in spite of this, a large number of candidates quoted times to a greater degree of accuracy. Most candidates gained at least partial credit for accuracy which was assessed by looking at the increase of the time as **FA 5** was diluted.
- (b)(i)** Most candidates correctly calculated the rates using the expression given with only a few incorrectly rounding the answer or giving it to an inappropriate number of significant figures. Most also gave the correct unit (s^{-1}) with only a few giving s or including moles in some way.
- (ii)** It was not generally recognised that the total volume of solution was 70 cm^3 and so many candidates calculated this incorrectly.
- (iii)** This is an example in which the stated conclusion must follow the calculated data. If, for example, the values of rate in **(b)(i)** increase from Experiment 1 to Experiment 2 whilst the initial concentration of acid decreases, it cannot be correct to conclude that rate increases as concentration increases.
- (iv)** Since the question referred to the effect on **time** it was not acceptable to refer only to the effect on **rate**. To gain credit, candidates had to refer specifically to sulfuric acid producing a greater concentration of H^+ due to it being diprotic. It is not true to state, as many candidates did, that either of the two acids is stronger.
- (v)** This part was answered correctly by very few candidates. Most answers were based on an increase in surface area if a larger capacity beaker were used rather than the fact that the smaller depth of solution present meant that it would take longer for sufficient sulfur to form to obscure the insert.

Question 3

There was evidence that candidates were generally using the Qualitative Analysis Notes but errors/imprecision in the observations led to some incorrect conclusions.

- (a) Although nearly all candidates observed the formation of a white precipitate in both (i) and (ii) many also reported that both the precipitates remained when dilute hydrochloric acid was added. In (iii) a significant number observed that a gas was formed and some reported that the gas was acidic by using litmus paper. Very few identified the gas as sulfur dioxide. In (iv) a minority reported that the solution went green but more observed the formation of the colourless solution when sulfuric acid was added. In view of the conflicting evidence seen by many in (i) and (ii) it was perhaps not surprising that few candidates correctly identified the anion as being sulfite in (v). Credit was however given for candidates who stated that sulfate was present if they used the evidence of the insolubility of the precipitate formed with Ba^{2+} in hydrochloric acid. This erroneous conclusion did make the equation in (vi) difficult.
- (b) (i) Evidence that most candidates do use the Qualitative Analysis Notes included the use of the precise description of manganese(II) hydroxide. Most of the observations in the table were correct although the addition of aqueous ammonia to $\text{Ca}^{2+}(\text{aq})$ and $\text{Mg}^{2+}(\text{aq})$ did cause some problems.
- (ii) Most candidates interpreted their evidence correctly to gain at least partial credit for the identification of the cations present.
- (iii) Very few correct equations were seen. Many candidates wrote molecular, rather than ionic, equations and even more, who did write ionic equations, did not balance the number of OH^- ions needed.
- (iv) Very few candidates realised that increasing the concentration was the most effective way of making the appearance of a precipitate more noticeable. The most common answer seen was based on increasing the light level or using a dark coloured background.

CHEMISTRY

Paper 9701/36
Advanced Practical Skills 2

Key Messages

- Deductions must follow the practical results obtained.
- Candidates should take care when rounding values.
- Care must be taken to note the term used in the question and respond with an appropriate amount of precision/detail.

General Comments

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Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Very few candidates were unable to complete the practical work, and most were able to gain credit both for accuracy and in some parts of the calculation.

- (a) Candidates were instructed to 'read the instructions ... and draw a table for results in the space on page 3' and though most candidates drew acceptable tables, some used the outline table on page 4. The instructions also stated that times should be recorded to the nearest second but a significant minority recorded times to a greater accuracy than that requested. Since a burette was used to measure the volumes of **FB 1** and distilled water and the volumes to be used were quoted to 2 decimal places, it was expected that the volumes used should also be recorded in the table to this degree of accuracy.

In **Experiments 3–6** the four further volumes of **FB 1** chosen should not have been less than 6.00 cm^3 (as given in the instructions) but, for full credit, no volume should have been within 2.00 cm^3 of any other volume and the volumes chosen should be across the whole range of 6.00 to 20.00 cm^3 .

The competency of the candidate in carrying out the practical procedure was assessed by comparing the candidate's result with that of the Supervisor and, on this basis, most candidates were awarded at least partial credit

- (b) Most candidates were familiar with calculations involving concentrations and the number of moles present in (i), (ii) and (iii). In part (iv) however it was necessary to realise that the total volume of solution was 60 cm^3 . The vast majority of candidates used 20 cm^3 in their calculation. Most

candidates then correctly used their change in concentration to calculate the 'rate of reaction'. Some however did use incorrect powers of 10 in this calculation and a significant number gave incorrect values due to rounding errors.

- (c) Most candidates drew a graph with the x- and y- axes labelled correctly but a significant number did not choose scales such that the plotted points covered at least half of the available space in both directions. Credit was available for drawing a line of best fit and candidates were told that they should identify any points that they considered anomalous. This meant that credit could be awarded only if points, not identified as being anomalous, were distributed equally across both sides of the line.
- (d) The question actually stated that the conclusion must be deduced by using the graph and therefore a conclusion that could not be justified from the experimental data was not considered valid. This meant that the plot had to be linear and gradient had to be positive to conclude that the rate was proportional to concentration and it could not be concluded that they were directly proportional unless the line passed through the origin.
- (e) A precise answer of which volumes should be altered and which should be kept constant was required.
- (f) Since the question asks for the effect on **time**, answers based on rate could not gain full credit. Many answers were rather vague with a significant number of candidates recognising that in **Suggested modification 1** the time would be less but few related this to an increase in **percentage** error.

Suggested modification 2 produced less valid responses. Few candidates realised that the reaction time would stay the same and even fewer gave precise answers stating that the percentage error would increase as a result of the change in **volume**.

- (g) In (i) it was necessary to choose the reaction with the shortest reaction time and many candidates were successful in their choice. In this case only one reading of time is involved and therefore the percentage error in (ii) is based on the use of ± 0.5 s. A significant number of candidates doubled this value.

Question 2

Candidates should be advised that if no visible reaction is seen that they should report this in those terms or as 'no observable reaction' but stating 'no observation' is not acceptable since this could imply that the test had not actually been undertaken.

- (a) In the test with edta the original solution was blue and therefore it was necessary to state that the colour became a deeper/darker blue. This test is not one with which it is expected that candidates are familiar – it was included as an observation. The addition of potassium iodide gives a mixture of products but the formation of brown iodine should be evident. Most candidates correctly observed the precipitates formed with aqueous sodium hydroxide and aqueous ammonia but a significant number did not include the effect of adding excess reagent. Almost all recorded the formation of the white precipitates with $\text{Ba}^{2+}(\text{aq})$. These observations meant that many candidates correctly identified the anion and cations required for (ii). Part (iii) however proved much more challenging and only a small number of candidates realised that they should test for the presence of the ammonium ion by heating **FB 4** or **FB 5** with aqueous sodium hydroxide.
- (b) Many candidates did not observe the decolouration of acidified potassium manganate(VII) or did not realise that it was, in this case, being used to test for an organic reducing agent. Most though did recognise Tollens' test and the appearance of a silver mirror was a common observation. Most candidates were aware of the significance of 2,4-dinitrophenylhydrazine and the difference in behaviour of aldehydes and ketones with oxidising agents. Many also gave the correct change for the oxidation state of silver although in a minority of cases these were reversed or involved -1 .

CHEMISTRY

<p>Paper 9701/41 A2 Structured Questions</p>
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Key Messages

The question paper requires answers to be written in dark blue or black ink, the use of pencils by candidates in writing formulae, structures and equations is to be strongly discouraged. Pencilled text is sometimes too faint to read and also some candidates write over the pencil in ink so that their answers become illegible.

General Comments

Candidates need to show clear working in mathematical questions, as where a final answer is incorrect often credit can be obtained from correct working.

Comments on Specific Questions

Question 1

- (a) Most candidates gained full credit although occasionally $3s^23p^63d^2$ was seen for a calcium atom.
- (b) This was well answered by most candidates. Common incorrect responses included CaSO_4 and CaCl_2 as reactants.
- (c) (i) Many candidates gained credit here. A common error was omitting another observation such as a brown gas being evolved.
- (ii) The trend and its explanation in terms of cation size and polarisation of the anion was well understood by candidates. Some, however, wrote in terms of atomic, rather than cationic, size and did not clearly specify that the anion was undergoing polarisation.
- (d) (i) This proved difficult for many candidates who often confused this definition with that for the standard enthalpy of solution. The key point here was 1 mole of gaseous ions dissolving in water.
- (ii) Many correct calculations were seen. Common errors included +2259 (incorrect sign), -1945 (no 2x) and -2297 (-19 used).
- (e) This proved difficult for many candidates. Candidates often omitted the link of cation size to the strength of the ion – water attractions.

Question 2

- (a) Most candidates gained partial credit here. Common errors were for Si, P and S.
- (b) (i) This was well answered by candidates, although the pH values were often incorrect.
- (ii) Candidates were more confident with giving the products than with balancing the equation.

Question 3

- (a) Many candidates did not relate their definition to transition elements.
- (b)(i) Most candidates correctly identified dative covalent or co-ordinate bonding,
 - (ii) Most candidates gained partial credit here. Common errors included suggesting that BF_3 can act as a ligand.
- (c) Candidates should have been able to apply their knowledge of transition metal reactions here.

Question 4

- (a) Many candidates were not secure in their knowledge of this type of reaction or the correct use of curly arrows.
- (b)(i) Some candidates did not gain credit as reference to concentration was frequently omitted.
 - (ii) This was well answered by candidates.
 - (iii) This was generally well known.
- (c)(i) Most candidates gained at least partial credit for the units. Many did not draw a tangent and calculate its gradient.
 - (ii) This was well answered.

Question 5

- (a)(i) Many diagrams were well drawn and correctly labelled.
 - (ii) Most candidates gained full credit.
 - (iii) Candidates were often unsure of the charge carriers in solution.
- (b)(i) This proved difficult for many candidates. Common errors were use of Ag^{2+} for Ag^+ and writing an unbalanced equation.
 - (ii) Many candidates showed correct methods in this calculation and received at least partial credit for the question.

Question 6

- (a) Most candidates answered this correctly.
- (b) Candidates struggled with the structure of the intermediate and again with showing a correct mechanism.
- (c)(i) Many candidates correctly identified the type of reaction as addition.
 - (ii) Many candidates did well applying the knowledge given in the question here.
- (d)(i) Many answers were too general and needed more detail for credit to be awarded.
 - (ii) Many candidates omitted the delocalised ring system.

Question 7

- (a) (i) Many candidates gave good attempts at the structures.
- (ii) The reagents were often correctly identified although some candidates did not include concentrated HCl or temperatures for both steps.
- (iii) This was well answered.
- (b) (i) Many candidates need to improve their understanding of π -bonds and σ -bonds.
- (ii) The question indicated that the product of each reaction is water-soluble, from which candidates should have concluded that the products were ionic organic salts. The correct product of **W** with cold HCl was often seen but a common error of the product of the reaction of **W** with $\text{CH}_3\text{CH}_2\text{Br}$ was the addition product. The type of reaction was not often awarded credit..

Question 8

- (a) (i) Most candidates gave the correct answer here.
- (ii) Almost all gave the correct answer here.
- (b) Parts (i), (ii) and (iii) were answered very well by most candidates.
- (c) Many candidates gave the correct response.
- (d) (i) This was well-answered by candidates. The most common error was phosphate.
- (ii) This was generally well known. A few candidates stated that hydrogen has no electrons or hydrogen is a very small atom, which were not sufficient for credit to be awarded.

Question 9

- (a) This was well known by many candidates.
- (b) Most candidates were able to be awarded partial credit but many did not give enough detail for the award of full credit.
- (c) (i) Almost all gave the correct answer here.
- (ii) Many candidates were unsure about the formation of a disulfide bond.
- (iii) Common incorrect answers included condensation and polymerisation.
- (d) (i) Candidates found identifying the proton types difficult.
- (ii) Candidates were often able to identify the correct splitting patterns or the number of adjacent protons for **E** and **F**, but rarely both.

Question 10

- (a) (i) Many candidates correctly identified the chiral centres here.
- (ii) Many candidates did not follow the rubric in this question and pointed their arrow to an atom rather than a bond.
- (iii) If candidates correctly identified the bonds in (ii), they were often awarded credit here for the structures.
- (b) Most candidates identified that hydrogen bonds would form between aspartame and water, but some did not state viable functional groups such as $-\text{OH}$ or $-\text{NH}_2$.

- (c) The majority of candidates gave a correct answer here. Common errors were with omission of or incorrect units.

CHEMISTRY

Paper 9701/42
A2 Structured Questions

Key Messages

The question paper requires answers to be written in dark blue or black ink, the use of pencils by candidates in writing formulae, structures and equations is to be strongly discouraged. Pencilled text is sometimes too faint to read and also some candidates write over the pencil in ink so that their answers become illegible.

General Comments

Candidates need to show clear working in mathematical questions, as where a final answer is incorrect often credit can be obtained from correct working.

Comments on Specific Questions

Question 1

- (a) Most candidates gained full credit although occasionally $3s^23p^63d^2$ was seen for a calcium atom.
- (b) This was well answered by most candidates. Common incorrect responses included CaSO_4 and CaCl_2 as reactants.
- (c) (i) Many candidates gained credit here. A common error was omitting another observation such as a brown gas being evolved.
- (ii) The trend and its explanation in terms of cation size and polarisation of the anion was well understood by candidates. Some, however, wrote in terms of atomic, rather than cationic, size and did not clearly specify that the anion was undergoing polarisation.
- (d) (i) This proved difficult for many candidates who often confused this definition with that for the standard enthalpy of solution. The key point here was 1 mole of gaseous ions dissolving in water.
- (ii) Many correct calculations were seen. Common errors included +2259 (incorrect sign), -1945 (no 2x) and -2297 (-19 used).
- (e) This proved difficult for many candidates. Candidates often omitted the link of cation size to the strength of the ion – water attractions.

Question 2

- (a) Most candidates gained partial credit here. Common errors were for Si, P and S.
- (b) (i) This was well answered by candidates, although the pH values were often incorrect.
- (ii) Candidates were more confident with giving the products than with balancing the equation.

Question 3

- (a) Many candidates did not relate their definition to transition elements.
- (b)(i) Most candidates correctly identified dative covalent or co-ordinate bonding,
 - (ii) Most candidates gained partial credit here. Common errors included suggesting that BF_3 can act as a ligand.
- (c) Candidates should have been able to apply their knowledge of transition metal reactions here.

Question 4

- (a) Many candidates were not secure in their knowledge of this type of reaction or the correct use of curly arrows.
- (b)(i) Some candidates did not gain credit as reference to concentration was frequently omitted.
 - (ii) This was well answered by candidates.
 - (iii) This was generally well known.
- (c)(i) Most candidates gained at least partial credit for the units. Many did not draw a tangent and calculate its gradient.
 - (ii) This was well answered.

Question 5

- (a)(i) Many diagrams were well drawn and correctly labelled.
 - (ii) Most candidates gained full credit.
 - (iii) Candidates were often unsure of the charge carriers in solution.
- (b)(i) This proved difficult for many candidates. Common errors were use of Ag^{2+} for Ag^+ and writing an unbalanced equation.
 - (ii) Many candidates showed correct methods in this calculation and received at least partial credit for the question.

Question 6

- (a) Most candidates answered this correctly.
- (b) Candidates struggled with the structure of the intermediate and again with showing a correct mechanism.
- (c)(i) Many candidates correctly identified the type of reaction as addition.
 - (ii) Many candidates did well applying the knowledge given in the question here.
- (d)(i) Many answers were too general and needed more detail for credit to be awarded.
 - (ii) Many candidates omitted the delocalised ring system.

Question 7

- (a) (i) Many candidates gave good attempts at the structures.
- (ii) The reagents were often correctly identified although some candidates did not include concentrated HCl or temperatures for both steps.
- (iii) This was well answered.
- (b) (i) Many candidates need to improve their understanding of π -bonds and σ -bonds.
- (ii) The question indicated that the product of each reaction is water-soluble, from which candidates should have concluded that the products were ionic organic salts. The correct product of **W** with cold HCl was often seen but a common error of the product of the reaction of **W** with $\text{CH}_3\text{CH}_2\text{Br}$ was the addition product. The type of reaction was not often awarded credit..

Question 8

- (a) (i) Most candidates gave the correct answer here.
- (ii) Almost all gave the correct answer here.
- (b) Parts (i), (ii) and (iii) were answered very well by most candidates.
- (c) Many candidates gave the correct response.
- (d) (i) This was well-answered by candidates. The most common error was phosphate.
- (ii) This was generally well known. A few candidates stated that hydrogen has no electrons or hydrogen is a very small atom, which were not sufficient for credit to be awarded.

Question 9

- (a) This was well known by many candidates.
- (b) Most candidates were able to be awarded partial credit but many did not give enough detail for the award of full credit.
- (c) (i) Almost all gave the correct answer here.
- (ii) Many candidates were unsure about the formation of a disulfide bond.
- (iii) Common incorrect answers included condensation and polymerisation.
- (d) (i) Candidates found identifying the proton types difficult.
- (ii) Candidates were often able to identify the correct splitting patterns or the number of adjacent protons for **E** and **F**, but rarely both.

Question 10

- (a) (i) Many candidates correctly identified the chiral centres here.
- (ii) Many candidates did not follow the rubric in this question and pointed their arrow to an atom rather than a bond.
- (iii) If candidates correctly identified the bonds in (ii), they were often awarded credit here for the structures.
- (b) Most candidates identified that hydrogen bonds would form between aspartame and water, but some did not state viable functional groups such as $-\text{OH}$ or $-\text{NH}_2$.

- (c) The majority of candidates gave a correct answer here. Common errors were with omission of or incorrect units.

CHEMISTRY

Paper 9701/43
A2 Structured Questions

Key Messages

The question paper requires answers to be written in dark blue or black ink, the use of pencils by candidates in writing formulae, structures and equations is to be strongly discouraged. Pencilled text is sometimes too faint to read and also some candidates write over the pencil in ink so that their answers become illegible.

General Comments

Candidates should be encouraged to use blank spaces on the question paper for their own working to aid them in answering questions.

Candidates should ensure that they have fully read all the information in the question before attempting an answer.

Question 1

- (a) Candidates were required to give specific statements about breaking the bonds between the Mg^{2+} ions and Cl^- ions, followed by forming bonds between these ions and water. Credit was often not awarded because statements did not contain sufficient detail.
- (b)(i) This was answered well.
- (ii) Many candidates gave a correct cycle and calculation. The most common incorrect answer, -754 , arose because candidates had not taken into account the two moles of chloride ions in each mole of magnesium chloride.
- (iii) This question asks for a comparison and so answers should make it clear what is being compared and with what. Answers such as 'it has a higher charge' were often seen and could receive no credit.
- (c) It was pleasing to see how well learned and clearly described this explanation was by many candidates.

Question 2

- (a) This was usually well answered but some Co^{3+} ions were described with 3d electrons present.
- (b)(i) Many answers described the ligands as 'surrounding' the metal ion. While this is true it does not distinguish between a complex ion and, for example, a solvated sodium ion. The answer needed to include a simple description of bonding between the ligands and the metal ion.
- (ii) Some answers incorrectly suggested physical properties, such as high melting point.
- (c) Candidates should have been able to apply their knowledge of transition metal reactions here.
- (d)(i) This was very well answered by the vast majority of candidates.
- (d)(ii) Many candidates correctly worked out that the three copper species had a total oxidation number of +7 and the consequent average oxidation number.

- (iii) Candidates found this question difficult, even when they had received credit for their answer to (ii).

Question 3

- (a) (i) This diagram was drawn well with many candidates receiving credit.
- (ii) Candidates made good use of the Data Booklet in answering this question.
- (b) Most candidates gave the correct answer here.
- (c) A few candidates gave well-argued answers, explaining the effect of lower Cl^- concentration on the electrode potential of the Cl_2/Cl^- half cell, and therefore on the overall cell potential. Some answers referred to the 'electrode potential of Cl^-/Cl_2 ' rather than the usual reduction potential; this often generated a confused answer.
- (d) (i) The incorrect half equations seen included the use of acid conditions, and half equations with H_2 or O_2 as products rather than reactants.
- (ii) Candidates struggled to answer here if their equations in (i) were not correct.
- (iii) Answers needed to refer to the specific reasons for the advantage rather than the vague 'environmentally friendly' or 'cheaper'. Specific and correct answers that referred to the ease and speed of recharging, or the non-toxicity of the water product, were comparatively rare.

Question 4

- (a) (i) Most candidates were confident in answering this question.
- (b) (i) This was generally answered well, although some stated that amphoteric substances are both acidic and alkaline, rather than both acidic and basic.
- (ii) The equation was constructed correctly by approximately half of all candidates.
- (c) (i) The correct information was usually quoted, although some gave the E^\ominus for the reduction of Sn^{2+} to Sn , rather than the oxidation of Sn^{2+} to Sn^{4+} .
- (ii) Many candidates were awarded full credit for this question.
- (d) (i) This was generally answered well. Some answers described 'oxidation and reduction happening at the same time', rather than 'oxidation and reduction of the same species/of germanium/of GeO '.
(ii) This completely novel context was found difficult by many. Candidates should be encouraged to use the blank spaces on question papers to write any useful working. In this case it was hoped that candidates would write the equation for the reaction of chlorine with cold aqueous sodium hydroxide. This could then have been used to work out the answer to the question. This approach was very rare.
(iii) Approximately half of all candidates gained credit for their diagram. Most of the incorrect diagrams had either a double or triple bond between the carbon atoms, or had no lone pair on one or both of the nitrogen atoms.
- (e) (i) The information 'All the phosphorus atoms in P_4 are trivalent' was often ignored.
(ii) Most candidates understood the principle of endothermic bond breaking and exothermic bond making and were able to use their answer to (i) to gain at least partial credit.
- (f) (i) Candidates made good attempts at this equation.
(ii) The instructions in the question were often not used to suggest the structure.

Question 5

- (a) (i) L and M were better answered than N.
- (ii) This was usually well answered.
- (iii) Candidates who described N correctly in (i) generally gained credit here.
- (iv) The correct answer, oxidation, was very rarely seen. Some candidates answered 'substitution, oxidation and cleavage'. If an approach like this is taken it must be all correct, in this reaction the first steps are addition and elimination rather than substitution.
- (b) (i) Candidates should be encouraged to use the question paper as it was intended. In this case the box was labelled 'intermediate' with the reagents on the left of it and products on the right. However, many answers were seen with the complete mechanism described in the intermediate box. Full credit was available for this approach, providing all necessary information was included.
- (ii) Candidates found it difficult to apply the information given in the question here.

Question 6

- (a) This was generally well answered by many candidates.
- (b) (i) Structures E and F were deduced correctly by many.
- (ii) The low temperature needed for the formation of the diazonium ion was better known than the use of NaNO_2/HCl in step 1. The use of alkaline conditions was not well known in step 2.

Question 7

- (a) Many candidates gained full credit here. The marking point most commonly not awarded was for the deoxyribose label.
- (b) This was generally well answered. However a significant number of candidates described transcription rather than replication.
- (c) (i) Good answers were generally seen here.
- (ii) Candidates knew the name of this technique.
- (iii) This was less well known, although many good answers referring to P-32 were seen.
- (iv) Candidates were able to apply their knowledge well here.

Question 8

- (a) (i) Answers that were both specific and clear were rare here. Common misconceptions were that retention time is the time of storage before injection, and the time during which each peak is being recorded.
- (ii) This was generally well answered.
- (iii) Answers that focused correctly on the time spent absorbed in the stationary phase were rare.
- (iv) Answers that focused correctly on the similar polarity, or similar/identical functional groups, were rare.

- (v) This was generally well answered.
- (b)(i) Approximately half of all candidates knew of the use of tetramethylsilane/TMS.
- (ii) Many candidates gained at least partial credit here. However many candidates did not refer to the splitting patterns as triplet and quartet.
- (iii) Part (b) of this question told candidates twice that **Y** is an ester, but a significant number did not use this information.

Question 9

- (a) This was generally well answered.
- (b) This was generally well answered, though 'amide' was an error seen on some scripts.
- (c)(i) The instruction to label a bond was missed by some candidates who may have been looking for answer lines such as were found elsewhere. Some candidates indicated an atom rather than a bond; others used a circle rather than an arrow. If such a circle included the correct bond and part of an incorrect bond no credit was given. However this question was generally well answered.
- (ii) This was generally well answered.
- (d) Some incorrect answers did not identify the relevant features of molecule **W** as instructed in the question. Other incorrect answers referred to –OH groups, these are not present in molecule **W**.

CHEMISTRY

Paper 9701/51

Planning, Analysis and Evaluation

Key Messages

Candidates should make sure that they have understood the purpose of an experiment that is described in a question. Their answers should relate directly to the procedures and problems relevant to this experiment.

Candidates must be careful to distinguish between a question that asks for a description and one that asks for an explanation.

Many candidates need to improve understanding of numbers of decimal places and numbers of significant figures.

General Comments

This paper seemed more accessible to candidates than the November 2014 paper but many candidates did not maintain the accuracy required to achieve full credit for questions. All questions require careful reading to appreciate the purpose of an experiment. The second question was generally answered better but many errors were made in plotting and drawing the graph. The more practical work that a candidate has carried out during their studies the more prepared and confident they will be in answering the questions on this paper.

Comments on Specific Questions

Question 1

- (a) This question was well answered by the majority of the candidates, usually by quoting the formulae relevant to carrying out a calculation. Candidates should remember however that a relationship such as amount in mol = (volume measured)/24.0 is only true if the volume is measured in dm³ and at room temperature and pressure; this should therefore be clearly stated in the answer.
- (b)(i) The question asked candidates to 'consider the effect of these different temperatures on the gas volume' but many did not refer to volume at all and therefore could not be awarded any credit.
- (ii) Although some candidates responded correctly, the explanations provided were often either unclear or contradictory to the response.
- (c) Most candidates were able to show a heating source and a gas syringe attached at the appropriate place or alternatively the collection of the displaced air over water using a measuring cylinder. However only a few appreciated that to transfer the heat to the sand required a fluid of an appropriate boiling point to be placed in the outside jacket of the Victor Meyer apparatus.
- (d) The inflammable nature of hexane was known by most candidates.
- (e)(i) Despite the wording of the question some answers incorrectly described what would happen when the hexane had been introduced into the apparatus.
- (ii) Those who appreciated that it was necessary to expel air from the apparatus before the tube containing hexane was dropped into the inner tube usually gave the correct response that the plunger of the syringe must be stationary (or no more bubbles must be observed where the method used was a collection over water). Incomplete answers focused on achieving a temperature in excess of 69 °C.

- (f) Nearly all candidates knew that the mass of hexane would be required. Many also correctly measured the volume of expelled air. Less frequent was a mention of the temperature and pressure whose measurement would be necessary to establish the amount in moles. A complete answer should have indicated that what is measured is the mass of the empty small tube and then the mass of the tube containing hexane and likewise the syringe reading before the hexane has been added followed by the reading after vapourisation has taken place.

Question 2

- (a) Nearly all candidates correctly recorded the temperature rise to one decimal place but a significant number gave the moles of barium hydroxide to three decimal places rather than three significant figures so that, for example, the first result was given as 0.003 mol instead of 0.00292 mol.
- (b) (i) Some of the graphs plotted were carefully done but many contained minor errors. Candidates should ensure that points are placed precisely.
- (ii) Too many candidates did not consider what was happening in the experiment and therefore tried to draw lines which had very little relationship to the results that had been obtained. It should have been appreciated that the temperature rise was directly proportional to the amount of barium hydroxide added until all the hydrochloric acid had been neutralised. At this stage a horizontal line parallel to the x-axis will be obtained. The vast majority gained credit for the point of interception of the two lines.
- (c) A good proportion of candidates correctly carried out the calculation to obtain the concentration of the hydrochloric acid. A common mistake was to use an incorrect ratio for moles of hydrochloric acid to moles of barium hydroxide.
- (d) Many candidates described the shape of the graph instead of providing an explanation for it. Many mentioned that heat was produced because the reaction is exothermic but a significant number then did not explain that the line of the graph became horizontal because the hydrochloric acid had been completely neutralised.
- (e) (i) Many candidates gained credit for the loss of heat to the surroundings. The second idea that more heat will be lost as temperatures approach maximum value because there is greater difference between the temperature reached and the temperature of the surroundings was not well understood.
- (ii) The main source of inaccuracy would have been the loss of heat from the open cup so adding a lid was sufficient to receive credit.
- (f) A good number of candidates gained partial credit for indicating that because the ethanoic acid was weak the temperature rise after each addition of barium hydroxide would be lower and would lead to a line on the graph that was less steep. A much smaller number of candidates appreciated that as the reacting quantities of hydrochloric acid and ethanoic acid would be the same the interception point of the ethanoic acid graph would occur vertically below the interception point of the hydrochloric acid graph. A significant number of candidates made the mistake of stating that because ethanoic acid was weak, less barium hydroxide would be required to achieve neutralisation.

Very few candidates understood that the maximum temperature rise obtained was less because some of the heat generated by the reaction would be used to ionise the ethanoic acid as the reaction took place.

CHEMISTRY

Paper 9701/52

Planning, Analysis and Evaluation

Key Messages

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Many candidates need to improve understanding of numbers of decimal places and numbers of significant figures.

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- (d) The inflammable nature of hexane was known by most candidates.
- (e)(i) Despite the wording of the question some answers incorrectly described what would happen when the hexane had been introduced into the apparatus.
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- (f) Nearly all candidates knew that the mass of hexane would be required. Many also correctly measured the volume of expelled air. Less frequent was a mention of the temperature and pressure whose measurement would be necessary to establish the amount in moles. A complete answer should have indicated that what is measured is the mass of the empty small tube and then the mass of the tube containing hexane and likewise the syringe reading before the hexane has been added followed by the reading after vaporisation has taken place.

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- (a) Nearly all candidates correctly recorded the temperature rise to one decimal place but a significant number gave the moles of barium hydroxide to three decimal places rather than three significant figures so that, for example, the first result was given as 0.003 mol instead of 0.00292 mol.
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- (ii) Too many candidates did not consider what was happening in the experiment and therefore tried to draw lines which had very little relationship to the results that had been obtained. It should have been appreciated that the temperature rise was directly proportional to the amount of barium hydroxide added until all the hydrochloric acid had been neutralised. At this stage a horizontal line parallel to the x-axis will be obtained. The vast majority gained credit for the point of interception of the two lines.
- (c) A good proportion of candidates correctly carried out the calculation to obtain the concentration of the hydrochloric acid. A common mistake was to use an incorrect ratio for moles of hydrochloric acid to moles of barium hydroxide.
- (d) Many candidates described the shape of the graph instead of providing an explanation for it. Many mentioned that heat was produced because the reaction is exothermic but a significant number then did not explain that the line of the graph became horizontal because the hydrochloric acid had been completely neutralised.
- (e) (i) Many candidates gained credit for the loss of heat to the surroundings. The second idea that more heat will be lost as temperatures approach maximum value because there is greater difference between the temperature reached and the temperature of the surroundings was not well understood.
- (ii) The main source of inaccuracy would have been the loss of heat from the open cup so adding a lid was sufficient to receive credit.
- (f) A good number of candidates gained partial credit for indicating that because the ethanoic acid was weak the temperature rise after each addition of barium hydroxide would be lower and would lead to a line on the graph that was less steep. A much smaller number of candidates appreciated that as the reacting quantities of hydrochloric acid and ethanoic acid would be the same the interception point of the ethanoic acid graph would occur vertically below the interception point of the hydrochloric acid graph. A significant number of candidates made the mistake of stating that because ethanoic acid was weak, less barium hydroxide would be required to achieve neutralisation.

Very few candidates understood that the maximum temperature rise obtained was less because some of the heat generated by the reaction would be used to ionise the ethanoic acid as the reaction took place.

CHEMISTRY

Paper 9701/53

Planning, Analysis and Evaluation

Key Messages

Candidates who have experienced practical work throughout their A Level Chemistry course show an increased success in an examination of this nature.

Overwriting text and especially numbers is to be avoided, instead, candidates are recommended to clearly cross out the original and write the new answer close by.

In graph plotting a simple clear cross is preferred to large dots. Care is necessary in plotting points, especially those that should lie directly on a grid line.

General Comments

Some candidates provide multiple responses to a simple question which sometimes contradict each other. It is understandable that candidates often commit their reasoning to paper but this has the possibility of introducing contradiction. Thus in **Question 2(d)**, a sufficient answer would be 'equilibrium has not been reached' but that was sometimes contradicted by 'and some of the NO₂ leaks out from the apparatus'.

The command words 'state' or 'what' in questions do not require extensive answers unlike 'explain' or 'describe' which do. The set-up of the examination provides sufficient space or lines for the question answer (with some extra) so it is not always necessary to use all the available space. Candidates should be encouraged to directly respond to each individual question in a straightforward way.

It was very pleasing to see that most candidates correctly quoted their calculations in **2(b)** and **2(c)(ii)** to the required three significant figures.

Comments on Specific Questions

Question 1

- (a) (i) The majority of the candidates gave the correct reactivity sequence, expressed in a variety of ways. Candidates should ensure that where a comparison is required in an answer this is clearly stated, e.g. a full halogen trend was necessary so 'chlorine is the most electronegative' is true but needed a comparison between all three halogens. Many incorrect answers listed characteristics such as size or electron shells which were not relevant to the question. Too many candidates answered by referring to ions.
- (ii) Again, the majority of the candidates gave the correct reactivity sequence, expressed in a variety of ways. The reactivity explanation here in terms of bond length or halogen size was better answered than in (i) but again many answers did not include a comparison between all three halogens. Too many answers listed characteristics such as electronegativity, electron shells or even intermolecular forces of attraction which were not relevant to the question. Again, too many candidates answered by referring to ions.

- (b)(i)** Most candidates were not able to give correct answers for both variables.
- (ii)** This question was not well answered. The common error was to consider that the three halogenoalkanes were in solution and to answer in terms of the amount of moles in solution.
- (iii)** Most candidates gave a correct suggestion for the first bullet point.

Many candidates correctly suggested the use of a thermostatically controlled water bath; some then went on to include the use of a Bunsen burner. Candidates should be encouraged to consider any hazard information that has been provided. The second marking point was more rarely awarded. It required a timer to be started at the same time the reagents were mixed. Most answers did not refer to timing, or its necessary simultaneous start.

The requirement for a 'stopping' reagent produced a wide range of answers. A non-interfering acid was required to react with the sodium hydroxide. HCl would not do nor any other halide containing acid as they would interfere. Silver nitrate, potassium manganate (VII) and indicators were common incorrect responses.

There was an amount of contradiction in the final marking point. Whilst the question clearly states that the reaction had been stopped, many stated that the standing time was necessary for the reaction to complete, rather than for the settlement of the precipitate.

- (iv)** Most candidates correctly chose filtration (or centrifugation) as a way of obtaining and weighing the precipitate. Unfortunately many omitted the need to dry the precipitate. A number of candidates believed that weighing the apparatus complete with chemicals before and after the reaction (2 minutes) would give the mass of precipitate.
- (c)** Most candidates were successful here with either the fire or inhalation risk in terms of keeping away from naked flames or using a fume cupboard.

Question 2

- (a)** Most candidates were awarded credit here. The most common errors were to have an inverted expression or an incorrect chemical formula.
- (b)** Most candidates gained full credit for the data which required squaring a number and stating it to 3 significant figures. The most common error was in the final value of 0.000590 which was given as 0.00590 or 0.00059.
- (c)(i)** Candidates need to take care with plotting graph points. All of the x values were on grid lines as were four of the y values. These four points were required to be exactly on the cross of the two grid lines, with no tolerance, as no judgement within a square was required. However, many of these missed the junction of the grid lines. For the other points a tolerance of half a square (provided the point was in the correct square) was allowed. There was a fair degree of imprecision in the plotting of many points including making the drawn points too large. It is recommended that candidates use a small pencil x to plot each point.

When drawing the line of best fit, the role of the origin should always be considered. This graph was of the form $y = mx$, so the line of the relationship must go absolutely through the origin. Many candidates' lines just missed the origin, so candidates should be advised to ensure that their lines do exactly go into the origin if that is appropriate. A number of candidates did not carry their lines into the origin but ended them at the first point.

As most of the points were a good fit on the best line, then the lines drawn were generally very good with only a very few having discontinuities or bends.

- (ii)** Whilst the question asked for two sets of values for calculation, a number of candidates gave just one x value and one y value. A few did not give the two co-ordinates in the standard $x_1, y_1 : x_2, y_2$ format. Many candidates chose table points for their co-ordinates. This choice worked well in this context since the points were mostly on the line. Sometimes the chosen table points were mis-

plotted and some chose 0.00300,0.500 which was usually above the plotted line so could not be used. Candidates should be encouraged to take co-ordinates from the line itself. The origin was acceptable as one of the co-ordinates provided the line was in the origin. Usually the slope was calculated correctly with very few having an inverted expression or squaring the already squared NO_2 value. Most candidates did give their correct result to three significant figures as required in the question.

- (d) The anomaly was usually identified correctly but the reason not so well done. Even though the question asked for the most anomalous point some candidates identified two (or more). The reason given was often correct but sometimes it was simply suggested that the measurements were taken too early. Some suggested that the temperature was changed but were not specific about in what way.
- (e) (i) Most candidates realised that the second line would start at the same point as the original line but be of steeper gradient. The line should start at the origin. A number of candidates had the inverse with a line below of lower gradient (presumably misunderstanding the sign of the enthalpy change). A few candidates had a parallel line which could not be chemically explained.
- (ii) The explanation of the line needed to agree with the line the candidate drew and the majority of candidates were successful here. A number of different ways of explaining the line e.g. the forward reaction is promoted (with increasing temperature), more NO_2 would be produced, etc. were acceptable.
- (iii) This was generally answered quite well. It is worth noting that a simple answer, 'increased' was perfectly adequate and did not need the elaboration that many candidates supplied.
- (iv) This was generally not as well answered as (iii). As an equilibrium constant, it is temperature variable, pressure having no effect. Most incorrect answers were K_c decreases.
- (f) Many candidates realised that as all of the NO_2 must have come from N_2O_4 so applying the stoichiometric ratio of 1:2 the reacted N_2O_4 must have been $0.0729/2 = 0.03645$ which needed to be added to 0.900. Most incorrect answers used a ratio of 1:1 and some tried an involved calculation based on an equilibrium constant expression.