

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to the candidates.

Only five questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 3, 5, 7, 9, and 19**. The questions at the end of the paper were answered no better but no worse than the questions that preceded them, suggesting that most candidates found they had sufficient time to complete the paper properly.

Nine questions can be said to have been found to be particularly difficult. 25% or less of candidates chose the correct responses to each of **Questions 8, 10, 14, 17, 21, 23, 33, 35 and 40**.

Comments on Specific Questions

Question 8

23% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 55% of candidates. It seems likely that candidates who chose **A** did so in the belief that SiO_2 is simple molecular.

Question 10

19% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 42% of candidates. Option **A** arose if candidates used the enthalpy of combustion of $\text{C} + \text{H}_2$ for the third part of the Hess's law cycle, instead of $2\text{C} + 3\text{H}_2$ which would have been correct.

Question 14

10% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 45% of candidates. Many candidates therefore did not know that BaCO_3 decomposes at a higher temperature than MgCO_3 .

Question 17

23% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answers were **B**, chosen by 26% of candidates, and **C**, chosen by 32%. These numbers suggest that many candidates guessed their answer.

Question 21

10% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 52% of candidates. The low number of correct answers suggests some candidates may not have appreciated the importance of the word **not** in bold in the question.

Question 23

23% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 55% of candidates. However, if $n=4$ (choice **A**) then the molecule C_4H_{10} must be splitting to give C_2H_6 and C_2H_4 , neither of which have structural isomers.

Question 33

19% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 39% of candidates. This suggests that while some candidates knew that SiO_2 has a giant structure, a smaller number knew that the baked clay in pottery does too.

Question 35

23% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answers were **A**, chosen by 26% of candidates, and **C**, chosen by 35%. These numbers suggest that many candidates guessed their answer.

Question 40

23% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 42% of candidates. Candidates who chose **B** realised that the $\text{C}=\text{C}$ bond in oleic acid will react with bromine, but they also erroneously believed that oleic acid can be oxidised under the conditions given.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General Comments

This examination paper provided a suitable but difficult challenge to the candidates.

Seventeen 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, 5, 6, 7, 9, 12, 13, 14, 19, 25, 27, 28, 30, 31, 32, 37** and **39**. Since **Questions 37** and **39** are on this list it can be suggested that most candidates found they had sufficient time to complete the paper properly.

Five questions can be said to have been found to be particularly difficult. 35% or fewer candidates chose the correct responses to each of **Questions 11, 20, 21, 23**, and **33**.

Comments on Specific Questions

Question 11

25% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 47% of candidates. **D** should have been discounted by candidates because the equation given shows bonds forming in Y_2 molecules. Some candidates might have found it easier to recognise **A** as correct if they had rewritten the equation using familiar substances, for example, $CH_4(g) \rightarrow C(g) + 4H(g)$. Dividing ΔH by 4 will give a value for the C-H bond energy.

Question 20

28% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answers were **A**, chosen by 27% of candidates, and **B**, chosen by 32%. The question was very discriminating, with over half of the high-scoring candidates choosing **D**. The statistics show that almost all candidates knew that 3 C=C bonds contain 3 π bonds and not 6. Candidates who chose **A** probably did not include the σ bonds in the CH_2 and CH_3 groups. Candidates who chose **B** probably did not include the σ bond within each of the three C=C bonds.

Question 21

35% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 42% of candidates. The answer is **D** because if R is C_2H_5 then the right-hand carbon in the C=C bond would be bonded to two identical groups. **B** is incorrect because if R is Cl then both of the carbon atoms in the C=C bond would be bonded to two different groups, and the compound would have cis- and trans- isomers.

Question 23

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 41% of candidates. If $n=4$ (option **A**) then the molecule C_4H_{10} must be splitting to give C_2H_6 and C_2H_4 , neither of which have structural isomers. The answer is **C** because if $n=8$ the products of cracking are C_4H_{10} and C_4H_8 , both of which have structural isomers.

Question 33

34% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 48% of candidates. It is clear that the majority of candidates knew that SiO_2 has a giant structure, and that P_2O_5 does not. The difficulty for many arose with statement 2. Candidates needed to recall that 'baked clay found in crockery' is a ceramic material, and that ceramic materials have a giant molecular structure (syllabus statements 4f and 4g).

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General Comments

This examination paper provided a suitable challenge to the candidates.

Fifteen questions can be said to have been found to be easier. 70% or more of candidates chose the correct responses to each of **Questions 2, 3, 4, 6, 7, 8, 9, 13, 17, 18, 22, 23, 30, 32** and **37**. **Questions 39** and **40** were both answered correctly by a significant number of candidates, suggesting that most candidates found they had sufficient time to complete the paper properly.

Five questions can be said to have been found to be particularly difficult. 35% or fewer candidates chose the correct responses to each of **Questions 24, 27, 33, 34** and **38**. Three of these questions were from the organic sections of the syllabus.

Comments on Specific Questions

Question 24

26% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 51% of candidates. The question asks what can be deduced with certainty. Since both carboxylic acids and alcohols will give steamy fumes with PCl_5 it cannot be deduced with certainty that X is a carboxylic acid, or that it is an alcohol. However, the lack of a visible product with 2,4-DNPH shows that X is definitely not an aldehyde.

Question 27

25% of candidates chose the correct answer, **D**. The other three options were each chosen by approximately equal numbers of candidates, suggesting that many had guessed their answer. The question should be approached by counting the OH groups in the product X. Warm dilute H_2SO_4 will hydrolyse the ester link in santonin, producing two OH groups. Cold, acidified KMnO_4 will oxidise the two $\text{C}=\text{C}$ bonds in santonin, producing four more OH groups. This makes six in total.

Question 33

34% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 41% of candidates. This showed that many candidates did not appreciate that metals have a giant metallic structure, or that ceramics have a giant molecular structure.

Question 34

15% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answers were **A**, chosen by 34%, and **C**, chosen by 41%. The key to ruling out both **A** and **C** is statement 3, 'X and Y must both be in the same Group of the Periodic Table'. This statement is incorrect, X and Y could be in group 2, or one or both of them could be transition metals.

Question 38

33% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 44% of candidates. It can be deduced that the majority of candidates were confident that statement 1 is correct and statement 3 is incorrect. The difficulty therefore lay with statement 2. A possible (and well known) reaction between CH_4 and Cl_2 is the photochemical reaction $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$. The formation of HCl involves the reduction of a chlorine atom from oxidation state 0 to oxidation state -1, therefore the photochemical chlorination of methane is a redox reaction.

CHEMISTRY

Paper 9701/21

AS Structured Questions

Key Messages

Some candidates demonstrated a good knowledge of organic chemistry, though many were unsure about the difference between stereoisomerism (optical isomerism and *cis-trans* isomerism) and structural isomerism.

The drawing of the structural formulae of organic compounds continues to be a problem for many candidates. Structures must be clear and unambiguous with bonds clearly shown between the correct atoms. Information about the different types of formulae used in organic chemistry is given in section 10.1 of the syllabus.

Calculations were problematic where candidates did not adopt a logical approach and clearly set out method in their answers. Candidates should be encouraged to show all their working in numerical questions. Those who do this tend to make fewer mistakes and receive more credit.

Many candidates did not quote units for calculated quantities and there is still some confusion over the use of significant figures. Section 1(h)(iii) of the syllabus provides guidance on the latter. Candidates should also be careful when rounding calculated numbers up or down when obtaining an answer.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Level Chemistry syllabus. The overall standard achieved by candidates was very similar to that of last year, with most candidates showing some positive achievement.

Chemistry has a significant factual content with questions asking candidates to recall knowledge. There were many good answers to these questions but some candidates found knowledge recall difficult.

The more able candidates performed well on **Question 1**, carrying out the calculations with competence. **Question 2** however was less well done, with many candidates struggling with the equilibrium calculation.

Those questions which asked candidates to apply their knowledge and understanding in an unfamiliar context, notably **Question 5**, tended to be less well answered.

Comments on Specific Questions

Question 1

The calculation in this question was answered well by those candidates who read the question carefully and adopted a logical approach in their answer. A significant number of candidates did not understand the processes that were being described and struggled with their answers. One common mistake was to misuse the data given in the question.

- (a) Although this is a simple question, many candidates gave the formulae of compounds such as ZnBr_2 that would not react as described in the question. A small number of candidates gave names rather than formulae, as required by the question.

- (b)
- (i) There was a significant number of candidates who did not understand that the repeated heating was to drive off all of the water of crystallisation.
 - (ii) Many good answers were seen to this part with candidates correctly calculating the M_r of ZnSO_4 **and** using the appropriate difference in mass from the table of data. Some candidates rounded the answer down and did not receive credit.
 - (iii) This part was generally well answered.
 - (iv) Fewer candidates were able to answer this part successfully. Not all candidates gave their answer as a whole number.
- (c)
- (i) The conversion of grams to milligrams caused problems for candidates in this question. Some candidates used the M_r of anhydrous zinc ethanoate in their answers while a small number calculated the M_r of the hydrated salt that was given in the question.
 - (ii) Those candidates who calculated an answer to (i) were usually able to answer this part correctly. As in (b)(ii), some candidates rounded this value down to an inappropriate extent and hence did not receive full credit for their answers.

Question 2

A clear understanding of Le Chatelier's Principle is very important for success in AS Level Chemistry. Many candidates gave very good answers to the early parts of this question but fewer were able to complete the calculation in (d) successfully.

- (a)
- (i) This was well answered by most candidates.
 - (ii) This part was less well answered with a significant number of candidates giving answers that referred to intermolecular forces rather than the bond strength of the H–X bond.
- (b) This was correctly answered by the majority of candidates.
- (c) Both parts of this question attracted many good answers. A small number of candidates mistakenly considered the effects of the changes on the rate of reaction rather than the position of equilibrium.
- (d) While there was a pleasing number of correct answers, a significant number of these were obtained by using the solution to a quadratic equation which is unnecessary. Reference to section 7(f) of the syllabus clearly shows that such a method is not required.

Other candidates fared less well, usually because they were unable to deduce the number of moles of each component present in the equilibrium in terms of the changes to the initial amounts. The most common mistake made was to state the equilibrium moles of HI(g) to be y rather than $2y$.

Question 3

While many candidates showed good knowledge of the Haber process for the manufacture of ammonia, familiarity with the laboratory preparation of ammonia was less common.

- (a)
- (i) The majority of candidates gave a fully correct equation. A small number did not give state symbols as the question required.
 - (ii) This was generally well answered although some candidates were unsure of the operating pressure.
 - (iii) This too was well answered.

- (b)
- (i) Although the names of the two compounds used in the reaction were given, a significant number of candidates gave at least one incorrect formula.
 - (ii) Those candidates who gave correct formulae in (i) usually constructed a correct equation, although some were not correctly balanced.
 - (iii) This part was less well answered. Many candidates did not make a connection between the alkaline gas ammonia and the acidic drying agents concentrated sulfuric acid and phosphorus(V) oxide. Use of either of these would result in a reaction between the drying agent and ammonia.
- (c) There were some very good answers to this part but many answers showed insufficient attention to detail. A significant number of equations did not have their charges balanced. Many did not show a lone pair of electrons on the nitrogen atom of an ammonia molecule. A small number either omitted to show clearly the dative co-ordinate bond or drew it the wrong way round.

Some candidates did not give displayed formulae in their answer, as the question required, and hence did not receive full credit for an otherwise correct response.

Question 4

This question tested candidates' knowledge of some fundamental organic chemistry.

- (a)
- (i) While there were candidates who gave fully correct answers, many responses contained simple mistakes. Not all candidates wrote 'no reaction' when they believed that nothing would happen. In such cases, no credit could be given. A number of structural formulae were badly drawn.

A significant number of candidates thought that compounds A, E, and F would react with the reagents given when, in fact, no reaction takes place.

While there were many correct answers for compound B, some candidates thought that copper propanoate would be formed.

Responses to compound C were generally poor with many candidates not realising that C is an ester of methanoic acid which would undergo hydrolysis under alkaline conditions to give a salt of methanoic acid and an alcohol.

Relatively few candidates knew what will be formed by the reduction of compound D by NaBH_4 with many organo-boron compounds being given as the product.
 - (ii) Answers to this part were generally better with the oxidation of compound B by Fehling's reagent correctly identified. However, some candidates who chose this reaction were unable to state the colour change correctly.
- (b)
- (i) This was poorly done by many candidates who were unable to give the correct structure.
 - (ii) This part was well answered by many candidates.

Question 5

This question tested candidates' ability to use information to identify the potential stereoisomers of a compound of known molecular formula and then draw displayed formulae of them. Many candidates struggled with the identification of the stereoisomers. Displayed formulae were often very poorly drawn.

- (a)
- (i) Only a relatively small number of candidates stated clearly that the reaction with sodium shows that compound **X** must contain **either** a carboxylic acid group **or** an alcohol group.
 - (ii) Fewer candidates then stated clearly that a carboxylic acid group could not be present or that compound **X must** contain an alcohol group.
 - (iii) There were more correct answers to this part. Examiners did not accept the answer '...it contains a double bond...' because this statement does not make it absolutely clear that the double bond is between two carbon atoms.
- (b) There were relatively few good answers to this part. It was expected that candidates would draw a pair of *cis-trans* isomers and a pair of compounds showing optical isomerism in the relevant boxes.

One common mistake was to not read the restrictions on the structures of the isomers given as bullet points at the top of page 11 of the question paper. Thus there were many structures in which –OH groups were attached to the carbon atom of a carbon-carbon double bond or which did not have the molecular formula $C_4H_8O_2$.

Another common mistake was to draw bonds between the wrong atoms, such as in the sequence O–H–C–CH₂–. This was particularly true for the *cis-trans* isomers.

Drawings of the two chiral compounds were perhaps a little better but not all pairs were shown as a three-dimensional mirror object/mirror image pair.

There was also some confusion over the difference between stereoisomerism and structural isomerism. Candidates who drew a pair of functional group isomers or chain isomers received no credit.

CHEMISTRY

<p>Paper 9701/22 AS Structured Questions</p>
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Key Messages

Some candidates demonstrated a good knowledge of organic chemistry, though many were unsure about the difference between stereoisomerism (optical isomerism and *cis-trans* isomerism) and structural isomerism.

The drawing of the structural formulae of organic compounds continues to be a problem for many candidates. Structures must be clear and unambiguous with bonds clearly shown between the correct atoms. Information about the different types of formulae used in organic chemistry is given in section 10.1 of the syllabus.

Calculations were problematic where candidates did not adopt a logical approach and clearly set out method in their answers. Candidates should be encouraged to show all their working in numerical questions. Those who do this tend to make fewer mistakes and receive more credit.

Many candidates did not quote units for calculated quantities and there is still some confusion over the use of significant figures. Section 1(h)(iii) of the syllabus provides guidance on the latter. Candidates should also be careful when rounding calculated numbers up or down when obtaining an answer.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Level Chemistry syllabus. The overall standard achieved by candidates was very similar to that of last year, with most candidates showing some positive achievement.

Chemistry has a significant factual content with questions asking candidates to recall knowledge. There were many good answers to these questions but some candidates found knowledge recall difficult.

The more able candidates performed well on **Question 1**, carrying out the calculations with competence. **Question 2** however was less well done, with many candidates struggling with the equilibrium calculation.

Those questions which asked candidates to apply their knowledge and understanding in an unfamiliar context, notably **Question 5**, tended to be less well answered.

Comments on Specific Questions

Question 1

The calculation in this question was answered well by those candidates who read the question carefully and adopted a logical approach in their answer. A significant number of candidates did not understand the processes that were being described and struggled with their answers. One common mistake was to misuse the data given in the question.

- (a) Although this is a simple question, many candidates gave the formulae of compounds such as ZnBr_2 that would not react as described in the question. A small number of candidates gave names rather than formulae, as required by the question.

- (b)
- (i) There was a significant number of candidates who did not understand that the repeated heating was to drive off all of the water of crystallisation.
 - (ii) Many good answers were seen to this part with candidates correctly calculating the M_r of ZnSO_4 **and** using the appropriate difference in mass from the table of data. Some candidates rounded the answer down and did not receive credit.
 - (iii) This part was generally well answered.
 - (iv) Fewer candidates were able to answer this part successfully. Not all candidates gave their answer as a whole number.
- (c)
- (i) The conversion of grams to milligrams caused problems for candidates in this question. Some candidates used the M_r of anhydrous zinc ethanoate in their answers while a small number calculated the M_r of the hydrated salt that was given in the question.
 - (ii) Those candidates who calculated an answer to (i) were usually able to answer this part correctly. As in (b)(ii), some candidates rounded this value down to an inappropriate extent and hence did not receive full credit for their answers.

Question 2

A clear understanding of Le Chatelier's Principle is very important for success in AS Level Chemistry. Many candidates gave very good answers to the early parts of this question but fewer were able to complete the calculation in (d) successfully.

- (a)
- (i) This was well answered by most candidates.
 - (ii) This part was less well answered with a significant number of candidates giving answers that referred to intermolecular forces rather than the bond strength of the H–X bond.
- (b) This was correctly answered by the majority of candidates.
- (c) Both parts of this question attracted many good answers. A small number of candidates mistakenly considered the effects of the changes on the rate of reaction rather than the position of equilibrium.
- (d) While there was a pleasing number of correct answers, a significant number of these were obtained by using the solution to a quadratic equation which is unnecessary. Reference to section 7(f) of the syllabus clearly shows that such a method is not required.

Other candidates fared less well, usually because they were unable to deduce the number of moles of each component present in the equilibrium in terms of the changes to the initial amounts. The most common mistake made was to state the equilibrium moles of $\text{HI}(\text{g})$ to be y rather than $2y$.

Question 3

While many candidates showed good knowledge of the Haber process for the manufacture of ammonia, familiarity with the laboratory preparation of ammonia was less common.

- (a)
- (i) The majority of candidates gave a fully correct equation. A small number did not give state symbols as the question required.
 - (ii) This was generally well answered although some candidates were unsure of the operating pressure.
 - (iii) This too was well answered.

- (b)
- (i) Although the names of the two compounds used in the reaction were given, a significant number of candidates gave at least one incorrect formula.
 - (ii) Those candidates who gave correct formulae in (i) usually constructed a correct equation, although some were not correctly balanced.
 - (iii) This part was less well answered. Many candidates did not make a connection between the alkaline gas ammonia and the acidic drying agents concentrated sulfuric acid and phosphorus(V) oxide. Use of either of these would result in a reaction between the drying agent and ammonia.
- (c) There were some very good answers to this part but many answers showed insufficient attention to detail. A significant number of equations did not have their charges balanced. Many did not show a lone pair of electrons on the nitrogen atom of an ammonia molecule. A small number either omitted to show clearly the dative co-ordinate bond or drew it the wrong way round.

Some candidates did not give displayed formulae in their answer, as the question required, and hence did not receive full credit for an otherwise correct response.

Question 4

This question tested candidates' knowledge of some fundamental organic chemistry.

- (a)
- (i) While there were candidates who gave fully correct answers, many responses contained simple mistakes. Not all candidates wrote 'no reaction' when they believed that nothing would happen. In such cases, no credit could be given. A number of structural formulae were badly drawn.

A significant number of candidates thought that compounds A, E, and F would react with the reagents given when, in fact, no reaction takes place.

While there were many correct answers for compound B, some candidates thought that copper propanoate would be formed.

Responses to compound C were generally poor with many candidates not realising that C is an ester of methanoic acid which would undergo hydrolysis under alkaline conditions to give a salt of methanoic acid and an alcohol.

Relatively few candidates knew what will be formed by the reduction of compound D by NaBH_4 with many organo-boron compounds being given as the product.
 - (ii) Answers to this part were generally better with the oxidation of compound B by Fehling's reagent correctly identified. However, some candidates who chose this reaction were unable to state the colour change correctly.
- (b)
- (i) This was poorly done by many candidates who were unable to give the correct structure.
 - (ii) This part was well answered by many candidates.

Question 5

This question tested candidates' ability to use information to identify the potential stereoisomers of a compound of known molecular formula and then draw displayed formulae of them. Many candidates struggled with the identification of the stereoisomers. Displayed formulae were often very poorly drawn.

- (a)
- (i) Only a relatively small number of candidates stated clearly that the reaction with sodium shows that compound **X** must contain **either** a carboxylic acid group **or** an alcohol group.
 - (ii) Fewer candidates then stated clearly that a carboxylic acid group could not be present or that compound **X must** contain an alcohol group.
 - (iii) There were more correct answers to this part. Examiners did not accept the answer '...it contains a double bond...' because this statement does not make it absolutely clear that the double bond is between two carbon atoms.
- (b) There were relatively few good answers to this part. It was expected that candidates would draw a pair of *cis-trans* isomers and a pair of compounds showing optical isomerism in the relevant boxes.

One common mistake was to not read the restrictions on the structures of the isomers given as bullet points at the top of page 11 of the question paper. Thus there were many structures in which -OH groups were attached to the carbon atom of a carbon-carbon double bond or which did not have the molecular formula $\text{C}_4\text{H}_8\text{O}_2$.

Another common mistake was to draw bonds between the wrong atoms, such as in the sequence $\text{O-H-C-CH}_2\text{-}$. This was particularly true for the *cis-trans* isomers.

Drawings of the two chiral compounds were perhaps a little better but not all pairs were shown as a three-dimensional mirror object/mirror image pair.

There was also some confusion over the difference between stereoisomerism and structural isomerism. Candidates who drew a pair of functional group isomers or chain isomers received no credit.

CHEMISTRY

Paper 9701/23

AS Structured Questions

Key Messages

Some candidates demonstrated a good knowledge of organic chemistry, though many were unsure about the difference between stereoisomerism (optical isomerism and *cis-trans* isomerism) and structural isomerism.

The drawing of the structural formulae of organic compounds continues to be a problem for many candidates. Structures must be clear and unambiguous with bonds clearly shown between the correct atoms. Information about the different types of formulae used in organic chemistry is given in section 10.1 of the syllabus.

Calculations were problematic where candidates did not adopt a logical approach and clearly set out method in their answers. Candidates should be encouraged to show all their working in numerical questions. Those who do this tend to make fewer mistakes and receive more credit.

Many candidates did not quote units for calculated quantities and there is still some confusion over the use of significant figures. Section 1(h)(iii) of the syllabus provides guidance on the latter. Candidates should also be careful when rounding calculated numbers up or down when obtaining an answer.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Level Chemistry syllabus. The overall standard achieved by candidates was very similar to that of last year, with most of them showing some positive achievement.

Chemistry has a significant factual content with questions asking candidates to recall knowledge. There were many good answers to these questions but some candidates found knowledge recall difficult.

The more able candidates performed well on **Question 1**, coping well with the calculations.

The questions which asked candidates to apply their knowledge and understanding in an unfamiliar context, notably **Question 5**, discriminated well between candidates.

Comments on Specific Questions

Question 1

The calculation in this question was answered well by those candidates who read the question carefully and adopted a logical approach in their answer. A significant number of candidates clearly did not understand the processes that were being described and struggled with their answers.

In the calculation parts of the question, many candidates did not give their answers to three significant figures as requested and therefore could not be awarded credit.

- (a)
- (i) Most candidates gave the correct equation. A few balanced their equation incorrectly with 9O_2 , forgetting the oxygen present in the glucose molecule.
 - (ii) Many good answers were seen to this part with the majority of candidates correctly calculating the M_r of $\text{C}_6\text{H}_{12}\text{O}_6$ and using it correctly. About half of the candidates expressed their answer as 40 mol which could not receive credit because the question expressly required the answer to be given to three significant figures.
 - (iii) This part was correctly answered by many candidates.
- (b)
- (i) The equation was given correctly by most candidates.
 - (ii) The majority of candidates correctly calculated the M_r of octane (114) and many then used its density to show that the mass of 4.00 dm^3 of octane is 2800 g. However, a significant number of candidates had the power of ten incorrect in the final answer.
 - (iii) This part proved to be more testing and only the more able candidates correctly deduced the mass of CO_2 correctly. The calculation requires the correct use of the answers to (i) and (ii).
- (c) There were some good answers to this part which were obtained by combining the answers to (a)(iii) and (b)(iii) with careful attention being paid to the units of mass and length.
- (d) This was well known. A small number of candidates unfortunately gave the name of the pollutant, not the formula as requested.

Question 2

Many candidates showed good knowledge of the reactions in this question although some of the explanations were not of the same standard.

- (a)
- (i) Most candidates knew that steamy or white fumes would be seen.
 - (ii) This equation was well known.
 - (iii) Examiners expected candidates to state clearly that a strong acid is one which is 'completely ionised'. Some candidates did not mention ions or used rather vague statements such as an acid which is 'completely dissociated'.
- (b)
- (i) There were some good answers to this part which showed that many candidates had first-hand experience of the reaction.
 - (ii) A significant number of candidates did not explain that concentrated sulfuric acid oxidises HI. Answers relating to the bond strengths of HI or NaI were common, and incorrect.
- (c)
- (i) This was well answered by most candidates.
 - (ii) The reaction in which $\text{AgCl}(s)$ is formed was well known but few candidates knew the formula of the complex formed when this precipitate is dissolved in $\text{NH}_3(aq)$.
 - (iii) As with (i), this was generally well answered although a small number of candidates gave descriptions for sodium bromide rather than sodium iodide.

Question 3

A clear understanding of Le Chatelier's principle is very important for success in AS Level Chemistry. Many candidates gave very good answers to the early parts of this question but fewer were able to complete the calculation in (d) successfully.

- (a) A large majority of candidates gave a correct answer such as the Haber process or the hydrogenation of fats.
- (b)
- (i) Most candidates correctly deduced that the equilibrium would move to the left. A smaller number explained this correctly in terms of fewer gas moles on the left hand side of the equation.
 - (ii) Some candidates were confused as to whether the forward reaction is endothermic or exothermic. The expected answer was that the equilibrium will move to the left because the forward reaction is endothermic **or** because the reverse reaction is exothermic.
- (c) Most candidates correctly deduced that the rate of reaction would increase because of the increased frequency of collisions.
- (d)
- (i) Virtually all candidates gave the correct expression for K_c .
 - (ii) An encouraging number of candidates gained full credit for this calculation. However, a significant number of answers were obtained by using the solution to a quadratic equation which is unnecessary. Reference to section 7(f) of the syllabus clearly shows that such a method is not required.

Some candidates fared less well, usually because they were unable to deduce the number of moles of each component present in the equilibrium in terms of the changes to the initial amounts.

Question 4

This question tested candidates' knowledge of some fundamental organic chemistry.

- (a)
- (i) More able candidates showed a good knowledge of these standard organic reactions. The common errors that were made are outlined below.
 - A The alkene formed by dehydration of the alcohol was offered.
 - B Some candidates thought a silver mirror was formed.
 - C $\text{CH}_3\text{CO}_2\text{H}$ was given instead of the salt $\text{CH}_3\text{CO}_2\text{K}$.
 - D A carboxylic acid was offered, formed by the supposed oxidation of a tertiary alcohol.
 - E 'No reaction' was sometimes given as the answer.
 - F CH_3COCl was often given as the product.
 - G The product which contained two carbon atoms was often given as the partially oxidised compound $\text{HO}_2\text{CCH}_2\text{OH}$.
 - (ii) Only compound G would produce a colour change - from purple to colourless. This was known by many candidates although a small number gave the colour change as from orange to green.

Question 5

This question tested candidates' ability to use information to identify the potential stereoisomers of a compound of known molecular formula and then draw displayed formulae of them. Many candidates struggled with the identification of the stereoisomers. Displayed formulae were often very poorly drawn.

In **(a)(ii)** and **(a)(iii)** candidates were not awarded credit if they did not give a fully displayed formula or drew a formula with incorrect bonding. Common errors were not showing the double bond in $-\text{CH}=\text{CH}_2$ or writing it as C_2H_3 . Some candidates also drew an incorrect bond sequence such as $-\text{O}-\text{H}-\text{C}\equiv$ or $\text{CH}_3-\text{C}\equiv$. In a displayed formula, the former suggests that there is a 2-valent hydrogen atom present while the latter implies that the bonding of the terminal methyl group is between the hydrogen atoms of the methyl group and the next carbon atom of the hydrocarbon chain.

(a)

- (i) Many candidates realised compound **H** was an alcohol which contained a $>\text{C}=\text{C}<$ bond and gave three correct structural isomers. Some candidates did not apply the data given and gave isomers with branched chains or an oxygen atom on a carbon atom involved in π bonding. Compound **J** was a ketone and compound **K** an aldehyde which some candidates got the wrong way round.
- (ii) Those candidates with suitable formulae for compound **H** invariably gave the correct displayed formula in this part.
- (ii) Once again, candidates with suitable formulae for **H** usually gave a correct displayed formula in this part. A few candidates did not label the chiral carbon atom as instructed.

CHEMISTRY

<p>Paper 9701/31 Advanced Practical Skills 1</p>
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Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places. Instructions about these are often given in the questions and should be adhered to.

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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

General Comments

The paper discriminated well, with the full range of credit being awarded. Every marking point on the paper was credited although several were not awarded frequently. There was little evidence of candidates not having sufficient time to complete the paper.

Comments on Specific Questions

Question 1

The majority of the candidates were able to complete the practical work successfully in the question, and most were able to gain credit for drawing the graph. Use of awkward scales in graphs should be discouraged as these frequently lead to incorrect plotting.

- (a) The majority of candidates gained at least partial credit for the accuracy of their experiments, and recorded their results in suitable tables. Credit was least frequently awarded for the correct calculation of the relative rate; some candidates ignored the instruction to record these to three significant figures or rounded their answers incorrectly. A greater proportion of candidates recorded the reaction times to one second than in previous sessions. Almost all candidates who carried out **Experiment 6** chose suitable volumes of **FA 1** and distilled water.
- (b) Almost all candidates labelled the axes correctly. Although most scales were suitable, some candidates chose scales which made it difficult to plot points accurately. Some plotted points were not within the correct half-square even when suitable scales were used. Candidates were given the benefit of the doubt over lines of best-fit: credit was awarded for a correct line omitting (0,0) or one passing through (0,0) with balanced points.

- (c) Only the more able gained credit for this question. Many candidates incorrectly discussed the probability of collisions between molecules. A substantial number noted the smaller surface area of solution in the 100 cm³ beaker without going on to comment on the increased depth. Some gave answers involving rate rather than time as required.
- (d) The most common error in this part was the incorrect calculation or the disregard of the total volume.
- (e) Candidates generally mentioned their straight line but the importance of (0,0) was often not referred to correctly. Some candidates appeared unaware of the meaning of direct proportionality.
- (f) This part was answered correctly by most candidates though some used rate rather than time in their calculations. Some incorrectly rounded their answers and consequently could not be awarded credit.
- (g) Almost all candidates copied their results for **Experiment 3** correctly and able candidates understood the necessity of controlled variables. However, some varied the volume of **FA 1** solution or did not maintain a constant total volume.

Question 2

The majority of candidates gained credit for this question, especially in the more familiar tests. The award of credit for this type of question relies on accurate reporting of observations and using the correct language even when the tests are not identical with those given in the Qualitative Analysis Notes. A greater proportion of candidates gave the correct name or formula of any reagent chosen than in previous sessions.

- (a) The majority of candidates gained at least partial credit for colour of the precipitates. However, fewer mentioned effervescence with either solution tested. Of those who did, many correctly chose to test the gas with limewater.
- (b) This part was answered well by many candidates. Some, who appeared to have a blue rather than colourless filtrate, did not report the colour of the precipitate correctly. Candidates should be encouraged to look at the precipitate through the base of the test-tube when faced with this situation.
- (c) The majority of candidates gained credit for the addition of starch indicator. However, a number gave the initial colour of the precipitate as red-brown, showing insufficient precision of response.
- (d) On the whole this section was completed more successfully than in previous sessions: candidates in some Centres have been well prepared for the type of recording necessary, and there were far fewer vague answers where precipitates were not mentioned. The most common errors were the reporting of a dark blue precipitate with **FA 3** and aqueous ammonia, and that the precipitate with **FA 4** was soluble in excess ammonia.
- (e) Almost all candidates gained partial credit for identifying the transition metal ions but incorrect results in (d) meant that fewer were able to receive further credit.
- (f) Many candidates selected an appropriate reagent and gave its full name or correct formula. Some selected barium chloride which would not have been suitable: barium ions would have reacted with any sulfate ions present in either **FA 4** or **FA 6** thus masking any difference in result between aluminium or lead ions and the chloride.
- (g) Able candidates answered this part correctly. Weaker candidates generally identified the halide in **FA 3** correctly but may have had insufficient practical experience to identify the halide in **FA 4**. Many realised that insufficient tests had been carried out on **FA 5** for any conclusion to be drawn.

CHEMISTRY

<p>Paper 9701/33 Advanced Practical Skills 1</p>
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Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Greater care is needed in supplying answers to the correct number of significant figures or decimal places. Instructions about these are often given in the questions and should be adhered to.

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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

General Comments

The paper discriminated well, with the full range of credit being awarded. Every marking point on the paper was credited although several were not awarded frequently. There was little evidence of candidates not having sufficient time to complete the paper.

Comments on Specific Questions

Question 1

The majority of the candidates were able to complete the practical work successfully in the question, and most were able to gain credit for drawing the graph. Use of awkward scales in graphs should be discouraged as these frequently lead to incorrect plotting.

- (a) The majority of candidates gained at least partial credit for the accuracy of their experiments, and recorded their results in suitable tables. Credit was least frequently awarded for the correct calculation of the relative rate; some candidates ignored the instruction to record these to three significant figures or rounded their answers incorrectly. A greater proportion of candidates recorded the reaction times to one second than in previous sessions. Almost all candidates who carried out **Experiment 6** chose suitable volumes of **FA 1** and distilled water.
- (b) Almost all candidates labelled the axes correctly. Although most scales were suitable, some candidates chose scales which made it difficult to plot points accurately. Some plotted points were not within the correct half-square even when suitable scales were used. Candidates were given the benefit of the doubt over lines of best-fit: credit was awarded for a correct line omitting (0,0) or one passing through (0,0) with balanced points.

- (c) Only the more able gained credit for this question. Many candidates incorrectly discussed the probability of collisions between molecules. A substantial number noted the smaller surface area of solution in the 100 cm³ beaker without going on to comment on the increased depth. Some gave answers involving rate rather than time as required.
- (d) The most common error in this part was the incorrect calculation or the disregard of the total volume.
- (e) Candidates generally mentioned their straight line but the importance of (0,0) was often not referred to correctly. Some candidates appeared unaware of the meaning of direct proportionality.
- (f) This part was answered correctly by most candidates though some used rate rather than time in their calculations. Some incorrectly rounded their answers and consequently could not be awarded credit.
- (g) Almost all candidates copied their results for **Experiment 3** correctly and able candidates understood the necessity of controlled variables. However, some varied the volume of **FA 1** solution or did not maintain a constant total volume.

Question 2

The majority of candidates gained credit for this question, especially in the more familiar tests. The award of credit for this type of question relies on accurate reporting of observations and using the correct language even when the tests are not identical with those given in the Qualitative Analysis Notes. A greater proportion of candidates gave the correct name or formula of any reagent chosen than in previous sessions.

- (a) The majority of candidates gained at least partial credit for colour of the precipitates. However, fewer mentioned effervescence with either solution tested. Of those who did, many correctly chose to test the gas with limewater.
- (b) This part was answered well by many candidates. Some, who appeared to have a blue rather than colourless filtrate, did not report the colour of the precipitate correctly. Candidates should be encouraged to look at the precipitate through the base of the test-tube when faced with this situation.
- (c) The majority of candidates gained credit for the addition of starch indicator. However, a number gave the initial colour of the precipitate as red-brown, showing insufficient precision of response.
- (d) On the whole this section was completed more successfully than in previous sessions: candidates in some Centres have been well prepared for the type of recording necessary, and there were far fewer vague answers where precipitates were not mentioned. The most common errors were the reporting of a dark blue precipitate with **FA 3** and aqueous ammonia, and that the precipitate with **FA 4** was soluble in excess ammonia.
- (e) Almost all candidates gained partial credit for identifying the transition metal ions but incorrect results in (d) meant that fewer were able to receive further credit.
- (f) Many candidates selected an appropriate reagent and gave its full name or correct formula. Some selected barium chloride which would not have been suitable: barium ions would have reacted with any sulfate ions present in either **FA 4** or **FA 6** thus masking any difference in result between aluminium or lead ions and the chloride.
- (g) Able candidates answered this part correctly. Weaker candidates generally identified the halide in **FA 3** correctly but may have had insufficient practical experience to identify the halide in **FA 4**. Many realised that insufficient tests had been carried out on **FA 5** for any conclusion to be drawn.

CHEMISTRY

<p>Paper 9701/34 Advanced Practical Skills 2</p>
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Key Messages

- Any results deemed anomalous by the candidate should be ringed or labelled on any graph drawn.
- Anomalous results should be discarded when a mean of results is to be calculated.
- Conclusions and inferences must be drawn from the actual results of tests carried out.

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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

General Comments

The paper discriminated well, with the full range of credit being awarded. Every marking point on the paper was credited although several were not awarded frequently. There was some evidence of candidates not having sufficient time to complete the paper.

Comments on Specific Questions

Question 1

The majority of the candidates were able to complete the practical work successfully in the question, and most were able to gain credit for drawing the graph. Use of awkward scales in graphs should be discouraged as these frequently lead to incorrect plotting.

- (a) The majority of candidates gained at least partial credit for the accuracy of their experiments. However, few gained full credit for the recording and display of their results. It is important that candidates display units as given in the syllabus: (s) or /s, and (s⁻¹) or /s⁻¹. Candidates should ensure that they follow the instructions given as not all recorded the times to one second or the rate to three significant figures. The calculations of (1000)/(reaction time) were generally correct.
- (b) The majority of candidates chose obvious scales and almost all gained credit for axes. However, those who chose awkward scales placed themselves at a disadvantage when it came to plotting the points. In this experiment (0,0) is a point on the graph but not all candidates used this. Most lines were drawn straight, though some candidates appeared to not have a ruler of suitable length.
- (c) (i) This question proved demanding with many candidates ignoring the information given about the total volume of each reaction mixture.

- (ii) Many candidates argued that if y increases as x increases then direct proportionality has been shown. Only the most able candidates could carry out ratio calculations successfully.
- (d) Some candidates mentioned their straight line but the (0,0) point was rarely mentioned. Few candidates appeared aware of the meaning of direct proportionality.
- (e) Many candidates gave answers involving rate instead of time as requested. Those who did mention time often gave an explanation quoting concentration instead of amount of substance.
- (f) Many candidates answered this in terms of errors in procedure rather than mentioning temperature (which should have been a controlled variable).
- (g)
 - (i) Few candidates identified the anomalous result so did not calculate an appropriate mean.
 - (ii) The majority of candidates were able to calculate the percentage uncertainty correctly using their answer from (i).
- (h) Only a small minority of candidates understood the concept of a fair test with proper control of variables. Common errors were to vary the volume of more than one **FB** solution or to not maintain a constant total volume.

Question 2

The majority of candidates gained credit for this question, especially in the more familiar tests. However, some appeared to have preconceived ideas of the observations they should be making. Not all substances tested or reagents used will be listed in the Qualitative Analysis Notes. The award of credit for this type of question relies on accurate reporting of observations using the correct language. A greater proportion of candidates gave the correct name or formula of any reagents chosen than in previous sessions.

- (a) This part was generally answered quite well with a suitable layout of observations being used by most candidates. The majority correctly reported the colours of the two precipitates and their insolubility in excess sodium hydroxide. However, fewer clearly showed that only **FB 6** was heated or that the gas turned damp red litmus paper blue.
- (b) The majority of candidates recorded the correct colours of precipitate and their insolubility in excess, though fewer noted that the green precipitate turned brown either here or in (a).
- (c) The award of credit for this part was reliant on good observations in (a) and (b) as there was no 'error carried forward' so proved difficult for a substantial number of candidates. However, some candidates were able to gain credit by identifying the cations from partially correct observations.
- (d)
 - (i) Most candidates correctly gave barium chloride or nitrate as the reagent to confirm the presence of sulfate or sulfite but a surprising number went on to add sulfuric acid to distinguish between the two. Some gave an appropriate acid but as the first reagent which was not correct.
 - (ii) The majority of candidates recorded the three white precipitates with barium chloride or nitrate but the solubility of these in an appropriate acid caused more problems and tended to be Centre-dependent. It is important that chemicals listed in the Confidential Instructions should give the expected reactions with the normal range of reagents.
 - (iii) Those candidates who carried out (ii) correctly were able to identify the anions successfully, though not all gave an explanation as requested.
- (e) Few candidates reported the three expected observations accurately. The effervescence was frequently omitted and the states of the products were also missing from many answers. However, some candidates correctly reported the gas relighting a glowing splint.

- (f) A surprising number of candidates reported that red litmus turned blue in **Test 1** and some that red litmus stayed red. However, of the candidates gaining the correct observation here, few went on to identify an allowable smell for an ester in **Test 2**. Many suggested an ester was present rather than answer the question which asked about the type of compound present in **FB 8**, that is, before the reaction with ethanol.

CHEMISTRY

<p>Paper 9701/35 Advanced Practical Skills 1</p>
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Key Messages

- Errors arising from measuring devices should reflect the precision of the instrument.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Candidates should be encouraged to refer to the Qualitative Analysis Notes for accepted descriptions of test results.

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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

General Comments

The paper proved accessible for all with the majority of candidates gaining credit in each question. Every marking point on the paper was credited although several were not awarded frequently. It was pleasing to note that candidates in many Centres had clearly noted points raised in previous reports.

Comments on Specific Questions

Question 1

The majority of the candidates were able to complete the practical work successfully in the question, and most graphs were drawn using sensible scales. However, it is evident that the calculation of errors still causes problems for many candidates.

- (a) It was clear from the results that the majority of candidates had followed the instructions carefully. Where credit was not awarded it was almost invariably because of recording the temperature inappropriately. Using the thermometer provided, the temperature could be ascertained to an accuracy of $\pm 0.5^{\circ}\text{C}$ and this therefore was the accuracy that was expected in each thermometer reading. A number of candidates recorded the values to the nearest whole number while a few recorded data to the nearest tenth of a degree.
- (b) As already noted, most candidates chose appropriate scales and labelled each axis correctly although some could not be awarded credit when the unit for time was given as seconds rather than minutes. The marking point for correct plotting was almost always credited with virtually every candidate being able to plot their data correctly. It was noteworthy that some did not plot the temperature at $t = 0$ minutes and also a few omitted the point at $t = 4$ minutes presumably as it was

not to form part of a straight line. Credit was available for drawing two straight lines and almost all gained credit for drawing the lines between time = 0 minutes and 3 minutes and between 5 minutes and 10 minutes. Far fewer were able to extrapolate these lines as required, a common error being to omit the extrapolated line from $t = 0$ to $t = 3$ up to the vertical line at $t = 3\frac{1}{2}$ minutes.

- (c)
- (i) Although many candidates answered this part correctly, for a number it caused some confusion as they interpreted it as referring to the temperature that the reaction mixture would have had at $t = 3\frac{1}{2}$ minutes. These candidates then sketched a best fit line from $t = 3$ to $t = 4$ minutes and saw where this intercepted the vertical at $t = 3\frac{1}{2}$ minutes. Although this allowed them to gain credit, it did make very clear that such candidates were not familiar with this graphical method of working out heats of reaction.
 - (ii) This was well answered with many candidates focusing on the observation that all the magnesium had reacted or disappeared. A few made statements about the fact that hydrochloric acid was still present after the reaction which would, of course, not have been apparent.
 - (iii) It appears that questions involving errors always provide a real challenge. It was comparatively rare to see the correct answer of 0.5°C for the error but it was even rarer for the maximum percentage error to be given correctly. Almost all candidates did not double the value of their error.
 - (iv) Many candidates realised correctly that a significant source of error would involve heat loss to the surroundings but they were then too vague in describing how this could be improved by suggesting general insulation of the cup or using a wind shield. Others referred to errors involving reading the thermometer at exactly the right time or to parallax error in reading the thermometer. Human errors are not credited as they should not occur in a carefully conducted practical examination.
 - (v) Most candidates focused on the increased rate of reaction and so gained partial credit; thereafter it was disappointing to see how many thought that the temperature rise must be less because the initial temperature had increased.

Question 2

The majority of candidates gained credit in all sections of this question with more recording titration results in an appropriate manner than in previous sessions.

- (a) Credit for using an acceptable mass of solid was commonly awarded. In the titration many candidates gave a suitable table with acceptable headings and then recorded the titration data to a suitable level of precision. Further marking points were available for the comparison of each candidate's value with that of the Supervisor and it was impressive to see a reasonable number of candidates receive credit for these.
- (b) It was pleasing to note that most candidates are now aware of the need to indicate, by suitable ticks or clearly showing the calculation, exactly how they have determined the result they suggest.
- (c)
 - (i) Most candidates were able to calculate the number of moles of sodium carbonate used but few then divided by ten to find the number in 25.0 cm^3 .
 - (ii) Almost all candidates applied the stoichiometric ratio from the equation correctly and also then divided by their average value from (b).
 - (iii) Of the calculation steps in the question, this proved the most difficult and it was clear that many candidates found themselves in unfamiliar territory. Even when the answer was correct it was noticeable how many needed to use a few lines of calculation rather than recognising this as a 20-fold dilution.

Question 3

This Qualitative Analysis exercise proved the most challenging with a significant number of candidates apparently carrying out the practical procedures correctly but then not recording the observations in an acceptable format. Many also did not seem able to use the information provided in the Qualitative Analysis Notes to interpret correctly the observations that they had made.

(a)

- (i) As always with such questions, the skill lies not so much in carrying out the required test but in making the appropriate observations. Here, for example, many candidates could not be awarded credit as they did not note the original colour of the solution or did not refer to a solution at all, simply saying, for example, 'it went green'.

The second test was better answered although here again some answers were rather muddled referring, for example, to the effects of excess sodium hydroxide before noting the formation of the precipitate or not noting the effect of excess reagent at all.

Observations for the test with silver nitrate gained many candidates credit but it was also apparent that some are still not making the most of the Qualitative Analysis Notes and so gave answers where they described the precipitate as bluish-white rather than white.

The last marking point was credited more often as it was only necessary to state the colour changes and most candidates recorded these correctly.

- (ii) All but the weakest candidates realised that **FA 4** must be a copper salt but thereafter the correct answer relied on the observation for the test with silver nitrate. Among the incorrect answers it was common to see a cream precipitate leading to the proposal of copper bromide as the identity of **FA 4**.
- (iii) Although a significant number of candidates realised that the brown colour was due to the formation of iodine, some answers suggested this was formed as a result of a displacement reaction whilst others confused iodine with iodide.

(b)

- (i) As in (a), there was a tendency to record the observations in insufficient detail although candidates were not penalised again for the same omission.

In the test with sodium hydroxide, a number of candidates again did not appear to use the Qualitative Analysis Notes so that their observations would match the notes. On adding hydrogen peroxide, most noted the change of colour but a significant number did not record the effervescence.

The test with barium chloride proved much more secure and most candidates gained credit here although it should be noted that a small number still refer to a white solution rather than a precipitate.

In the final part, to be awarded credit it was necessary to carry out the test to prove the formation of oxygen. This was included by only the most able candidates.

- (ii) In identifying the salt, the majority correctly noted the presence of the sulfate ion but the credit for Mn^{2+} was less often awarded. Common among the incorrect answers was iron(II) sulfate presumably because of an incorrect colour of precipitate with sodium hydroxide.
- (iii) It was noticeable that some weaker candidates made no attempt to answer this question although there was no evidence of time pressures elsewhere in their papers. Others simply recorded their observations for the addition of **FA 5** and did not go on to suggest or carry out their own test. Most who did use sodium hydroxide or aqueous ammonia then gave a correct observation.

CHEMISTRY

<p>Paper 9701/36 Advanced Practical Skills 2</p>
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Key Messages

- Errors arising from measuring devices should reflect the precision of the instrument.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Candidates should be encouraged to refer to the Qualitative Analysis Notes for accepted descriptions of test results.

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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

General Comments

The paper proved accessible with the majority of candidates gaining credit in each question. Every marking point on the paper was credited although several were not awarded frequently. It was pleasing to note that candidates in many Centres had clearly noted points raised in previous reports.

Comments on Specific Questions

Question 1

The majority of candidates gained credit in all sections of this question with more recording titration results in an appropriate manner than in previous sessions.

- (a) It was evident, from the comparison of each candidate's results with those of the relevant Supervisor that most candidates carried out the titration exercise with a reasonable degree of competence. As noted above, the majority recorded their results in a suitable format and included acceptable headings. Since the exact end-point of this titration is somewhat difficult to observe, it was pleasing to note how many candidates gained full credit for carrying out the procedure accurately.
- (b) It was also pleasing to note that a large number of candidates showed clearly, by using ticks or including their calculation, exactly how they derived the volume of **FB 2**. A small number did not quote their average correctly to two decimal places or included their rough titration result in their calculated value.
- (c) Most candidates were clearly familiar with the formulae that were needed to solve the volumetric-based problems so that many correct answers were seen. However, credit could not be

awarded when the 1000 needed in (i) and (iii) were omitted or answers were quoted to an insufficient number of significant figures. Since all values in the question were quoted to three significant figures, this was the number that was expected in the final answer, though answers given to four significant figures were also accepted.

- (d) Candidates appeared to find it very difficult to give precise comments on the possible effectiveness of the changes suggested in the practical procedure. Many responses were therefore too vague to be credited.

For student 1 it was necessary to recognise that starch was acting as the indicator. Whilst a number of candidates did imply this many stated that more starch would make the end-point better or that it would mean more thiosulfate would be needed.

The comment on the effect of adding more potassium iodide, as suggested by student 2, was also often confused, with it being commonly suggested that more iodine would be formed so that more thiosulfate would be needed. Since insufficient information was included in the question to allow candidates to actually calculate that the iodide ions were already in excess, well-expressed answers were accepted based on this being the case or it not being so. Those familiar with this type of titration were more likely to be aware that iodide ions would normally be in excess.

A precise answer was also needed on the possible effect of filtering the mixture before titration. Answers based on making the colour change at the end-point easier to see or the possible retention of iodine in the filter paper were acceptable but vague responses such as 'removes impurities' or 'gives a more accurate result' were not.

Question 2

The majority of the candidates were able to complete the practical work successfully in the question, and most graphs were drawn using sensible scales. However, it is evident that the calculation of errors still causes problems for many candidates.

- (a) It was clear from the results that the majority of candidates had followed the instructions carefully. The mass used was generally clearly calculated and was within the specified range. Where credit was not awarded in this part it was almost invariably because of the temperature being recorded inappropriately. Using the thermometer provided, the temperature could be ascertained to an accuracy of $\pm 0.5^{\circ}\text{C}$ and this therefore was the accuracy that was expected in each thermometer reading. A number of candidates recorded the values to the nearest whole number while a few recorded data to the nearest tenth of a degree.
- (b) As already noted, most candidates chose appropriate scales and labelled each axis correctly although some could not be awarded credit when the unit for time was given as seconds rather than minutes. The credit available for correct plotting was almost always awarded with virtually every candidate being able to plot their data correctly. It was noteworthy that some did not plot the temperature at $t = 0$ minutes and also a few omitted the point at $t = 4$ minutes presumably as it was not to form part of a straight line. Credit was available for drawing two straight lines and almost all gained credit for drawing the lines between time = 0 minutes and 3 minutes and between 5 minutes and 10 minutes. Far fewer were able to extrapolate these lines as required, a common error being to omit the extrapolated line from $t = 0$ to $t = 3$ up to the vertical line at $t = 3\frac{1}{2}$ minutes.
- (c) (i) Although many candidates answered this part correctly, for a number it caused some confusion as they interpreted it as referring to the temperature that the reaction mixture would have had at $t = 3\frac{1}{2}$ minutes. These candidates then sketched a best fit line from $t = 3$ to $t = 4$ minutes and saw where this intercepted the vertical at $t = 3\frac{1}{2}$ minutes. Although this allowed them to gain credit, it did make very clear that such candidates were not familiar with this graphical method of working out heats of reaction.
- (ii) Nearly all candidates recognised that it was necessary to use the formula, heat energy = $mc\Delta T$, and a large number of correct answers were seen. However a significant number of candidates incorrectly used the mass of solid as m in this formula.

- (iii) Nearly all candidates correctly calculated the number of moles of zinc used whilst the comparison with the number of moles of copper involved was a little more problematic.
- (iv) Most candidates divided their answer to (ii) by their answer to (iii) but a number chose the number of moles of copper. Most candidates correctly gave the sign as being negative but some apparently confused 'sign' with 'symbol' and stated that the sign was ΔH .
- (d) It appears that questions involving errors always provide a real challenge. It was comparatively rare to see the correct answer of 0.5°C for the error but it was even rarer for the maximum percentage error to be given correctly. Almost all candidates did not double the value of their error.

Question 3

This Qualitative Analysis exercise proved the most challenging with a significant number of candidates apparently carrying out the practical procedures correctly but then not recording the observations in an acceptable format. Many also did not seem able to use the information provided in the Qualitative Analysis Notes to interpret correctly the observations that they had made.

- (a)
 - (i) As always with such questions, the skill lies not so much in carrying out the required test but in making the appropriate observations. Here, for example, many candidates could not be awarded credit as they did not note the original colour of the solution or did not refer to a solution at all, simply saying, for example, 'it went blue'.

The second test was better answered although here again some answers were rather muddled referring, for example, to the effects of excess sodium hydroxide before noting the formation of the precipitate or not noting the effect of excess reagent at all.

The test using barium chloride or nitrate was generally secure.

- (a)
 - (ii) Most candidates correctly recognised that **FB 5** was a sulfate but many then went on to state that it also contained Cu^{2+} ions. This conclusion was often in spite of observations of green solutions or green precipitates in (i).

- (b)
 - (i) As in the first test in (a), there was a tendency to record the observations in insufficient detail although candidates were not penalised again for the same omission in this observation.

The observations in the second and third tests were generally correct.

- (b)
 - (ii) Most candidates correctly identified the anion in **FB 6** as being chromate(VI) but fewer were successful with **FB 7** and **FB 8**. This was in spite of all the relevant reactions being included in the Qualitative Analysis Notes.

- (b)
 - (iii) The Examiners allowed any test that would distinguish between the cations that the candidate had suggested in (ii). However, many candidates named a suitable reagent but did not go on to give the observations that would actually lead to the identification being confirmed.

- (c) In this case the Examiners credited responses that followed the candidate's suggestions for **FB 5** and **FB 8**. However the prediction had to follow the identities given. A number of candidates clearly did not obey the rubric in the question that they should 'not carry out this test' since their prediction of the formation of a white precipitate was the correct practical observation but did not follow from the substances that they had suggested.

- (d) Many candidates recognised that ethanol would be oxidised but there were a significant number of answers that suggested the formation of an ester.

- (e) Since this is not covered specifically in the Qualitative Analysis Notes, only the more able candidates could give acceptable tests. Weaker candidates tended to give negative tests; generally that there would be no reaction with aqueous sodium hydroxide or aqueous ammonia.

CHEMISTRY

Paper 9701/41

A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations which clearly explain what the numbers refer to.

General Comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who were well-prepared for the examination were able to tackle all of the questions. There was no evidence that candidates had insufficient time to complete the paper.

Candidates are reminded of the importance of careful reading of the question before they attempt an answer. Thus **Questions 3(b)** and **6(b)** required a fully-labelled diagram to be included; **Questions 4(a)**, **4(c)** and **5(c)(ii)** required both the reagents and conditions to be stated; **Question 3(a)** listed three bullet points to help candidates construct their answer for each type of catalysis.

This report should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

(a) Many candidates were able to give correct observations and balanced equations for both reactions. Most errors were usually results of incorrect equations by weaker candidates. There was also some uncertainty about the product of the reaction or writing a balanced equation.

(b) The majority of candidates were able to work through the steps logically, gaining some or all of the credit available. Credit was often awarded on the principle of error carried forward, either from an incorrect equation or calculation errors.

Quite a number of candidates did not link (iv) with (iii) and (v) with (iv).

Candidates found (vi) difficult and usually did not calculate the remaining moles of Fe^{3+} in the solution before carrying out the second step of this calculation.

(c) The most common errors were omitting the bond energy of Si–Si or Cl–Cl or using the bond energy of S–Cl (250 kJ mol^{-1}) for Si–Cl (359 kJ mol^{-1}).

(d) Although this was a relatively simple equation, a lot of candidates balanced the equation incorrectly or suggested that calcium had been oxidised.

Question 2

- (a)
- (i) Quite a number of candidates did not recognise the correct identities of **A** and **B**.
 - (ii) Most candidates gained credit here. The inclusion of a battery was, however, a common error.
- (b) Many candidates carried out the calculation in (i) successfully but (ii) and (iii) proved trickier with only the most able candidates scoring full credit.
- (c)
- (i) Most candidates gained credit here. However the charges for the ions were occasionally omitted or given incorrectly.
 - (ii) Many candidates did not recognise that $[\text{SO}_4^{2-}]$ was obtained by dividing $[\text{Ag}^+]$ by two.
- (d) Most candidates correctly identified the colours of the precipitates, although the explanations in respect to their relative solubilities were often too vague to be awarded credit.
- (e) This question was well answered by many candidates. Common errors were the omission of ΔH_{sol} becoming more endothermic or reference to the ionic radius of M^{2+} .

Question 3

- (a)
- (i) Almost all gave the correct answer here.
 - (ii) A pleasing number of candidates correctly identified a heterogeneous catalysed reaction. However, a lot of candidates seemed unable to recall an example of a homogeneous catalysed reaction, for example Fe^{2+} catalysed reaction of $\text{S}_2\text{O}_8^{2-}$ and I^- ions. Other common errors were unbalanced equations and the omission of how each of the catalysts decreases the activation energy.
- (b) This question caused problems for a significant number of candidates who did not realise that an intermediate level needed to be included in the diagram. Another common error was incorrect labelling of E_a and ΔH .

Question 4

- (a) Most candidates identified 'heat under reflux with acidified dichromate'.
- (b) Lots of candidates gave the correct name of the type of reaction here, though nucleophilic addition was a common error.
- (c) Although stronger candidates knew the correct reagents and conditions, weaker candidates omitted heat or aqueous conditions.
- (d)(e) This proved difficult for a significant number of candidates. Common errors included aldehyde in (d) and amine in (e).
- (f) This question caused problems for a significant number of candidates who seemed unable to draw upon knowledge from a range of areas of the organic syllabus. Candidates had most difficulty with the structures of capsaicin and **C**, whilst giving correct structures of **D**, **E** and **F**. Common errors were drawing propanoic acid for **E** and incorrectly connecting the nitrile group to the carbon chain in **F**.

Question 5

- (a) Many candidates correctly identified the functional groups as phenol and ketone.
- (b) This question caused problems for a significant number of candidates who seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. The reactions of phenol and the test for methylketones were poorly remembered. Many candidates were able to suggest suitable observations for each of the reactions, although drawing the structures of the organic product proved more difficult for some. Common errors were monosubstitution of bromine and more frequently the incorrect oxidation product from the iodoform reaction. Only the more able candidates identified the type of reaction in each case. The most common errors were reduction (with Na), electrophilic addition (with aqueous Br₂) and iodoform (with aqueous alkaline I₂).
- (c)
- (i) There were a number of poor drawings of structure here. Many candidates did not draw an amine for **J** (as stated in the question) or recognise that **K** was a diazonium salt.
- (ii) Although stronger candidates knew the reactants and conditions for both reactions, weaker candidates omitted one or both, e.g. not mentioning the aqueous conditions with step 2.
- (d) This question proved to be difficult with only the more able candidates suggesting a viable route via the acyl chloride. Partial credit was awarded to candidates that suggested heating compound **G** with propanoic acid in the presence of concentrated sulfuric acid.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section with performance slightly improved on previous years'.

Question 6

- (a) Many candidates completed the table correctly.
- (b) Candidates showed some knowledge of competitive and non-competitive inhibitors. In many cases, diagrams were not labelled and so did not receive credit. A few candidates incorrectly suggested that the inhibitor bonded to the substrate.
- (c) Most candidates correctly identified the pair basing and drew clear diagrams. Common errors were to give alanine rather than adenine and to omit the labelling of hydrogen bonding between the base pairs.

Question 7

- (a)
- (i) Many candidates gave the correct answer of electrophoresis here. Chromatography was an incorrect answer commonly seen.
- (ii)(iii) These were poorly answered with few candidates receiving full credit.
- (b)
- (i) A good number of candidates correctly labelled **X** on the diagram. However, sometimes the **X** was omitted or on the lower part of the diagram.
- (ii) A surprising number of candidates linked the suspect to the victim instead of the crime scene, which gained no credit
- (c) In this part, there seemed to be much uncertainty among candidates as to the required answers. Candidates could gain credit by different ways, e.g. using the mass spectrometry data, NMR spin-spin splitting patterns or NMR chemical shift values (see mark scheme). Many candidates understand mass spectrometry and were able to determine that **P** contains four carbons and quite

a few arrived at the correct structure of **P**. Methyl propanoate was a common error. However, many candidates had difficulty discussing splitting patterns, e.g. the quartet (at 4.1 ppm) shows an adjacent CH₃ group and the triplet (at 1.3 ppm) shows an adjacent CH₂ group. The presence of three signals in the NMR spectrum indicates that there are three different proton environments.

Question 8

- (a)
- (i) This was well done by the majority of candidates and reflected an understanding of the effect of pH on enzyme activity.
 - (ii) This was generally well answered but a surprising number of candidates incorrectly chose addition.
- (b) This was well answered and commonly candidates gained full credit by swapping over two adjacent groups in the lactic acid structure given in the question.
- (c)
- (i) This was very poorly answered with few candidates recognising that the ester linkage would be hydrolysed. Many candidates appreciated that the vinegar would degrade the packaging material but did not specify how it was achieved.
 - (ii) This was more successfully answered. Many candidates identified that the container would soften, although a number of candidates incorrectly suggested that the container would melt.
- (d)
- (i) A good number of candidates correctly showed a displayed ester linkage but gave structures which showed an extra oxygen atom in their repeat unit, gaining no credit.
 - (ii) This question proved difficult for many candidates who could not relate the structure to the intermolecular forces between the chains and did not indicate the groups involved. Hydrogen bonding was a common error.
 - (iii) Many candidates successfully gave a correct answer here, e.g. the co-polymer would have a higher melting point.

CHEMISTRY

Paper 9701/42

A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations which clearly explain what the numbers refer to.

General Comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who were well-prepared for the examination were able to tackle all of the questions. There was no evidence that candidates had insufficient time to complete the paper.

Candidates are reminded of the importance of careful reading of the question before they attempt an answer. Thus **Questions 3(b)** and **6(b)** required a fully-labelled diagram to be included; **Questions 4(a)**, **4(c)** and **5(c)(ii)** required both the reagents and conditions to be stated; **Question 3(a)** listed three bullet points to help candidates construct their answer for each type of catalysis.

This report should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

(a) Many candidates were able to give correct observations and balanced equations for both reactions. Most errors were usually results of incorrect equations by weaker candidates. There was also some uncertainty about the product of the reaction or writing a balanced equation.

(b) The majority of candidates were able to work through the steps logically, gaining some or all of the credit available. Credit was often awarded on the principle of error carried forward, either from an incorrect equation or calculation errors.

Quite a number of candidates did not link (iv) with (iii) and (v) with (iv).

Candidates found (vi) difficult and usually did not calculate the remaining moles of Fe^{3+} in the solution before carrying out the second step of this calculation.

(c) The most common errors were omitting the bond energy of Si–Si or Cl–Cl or using the bond energy of S–Cl (250 kJ mol^{-1}) for Si–Cl (359 kJ mol^{-1}).

(d) Although this was a relatively simple equation, a lot of candidates balanced the equation incorrectly or suggested that calcium had been oxidised.

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- (a)
- (i) Quite a number of candidates did not recognise the correct identities of **A** and **B**.
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- (b) This question caused problems for a significant number of candidates who did not realise that an intermediate level needed to be included in the diagram. Another common error was incorrect labelling of E_a and ΔH .

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- (a) Most candidates identified 'heat under reflux with acidified dichromate'.
- (b) Lots of candidates gave the correct name of the type of reaction here, though nucleophilic addition was a common error.
- (c) Although stronger candidates knew the correct reagents and conditions, weaker candidates omitted heat or aqueous conditions.
- (d)(e) This proved difficult for a significant number of candidates. Common errors included aldehyde in (d) and amine in (e).
- (f) This question caused problems for a significant number of candidates who seemed unable to draw upon knowledge from a range of areas of the organic syllabus. Candidates had most difficulty with the structures of capsaicin and **C**, whilst giving correct structures of **D**, **E** and **F**. Common errors were drawing propanoic acid for **E** and incorrectly connecting the nitrile group to the carbon chain in **F**.

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Overall, many candidates made a very satisfactory attempt at the questions in this section with performance slightly improved on previous years'.

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Question 8

- (a)
- (i) This was well done by the majority of candidates and reflected an understanding of the effect of pH on enzyme activity.
 - (ii) This was generally well answered but a surprising number of candidates incorrectly chose addition.
- (b) This was well answered and commonly candidates gained full credit by swapping over two adjacent groups in the lactic acid structure given in the question.
- (c)
- (i) This was very poorly answered with few candidates recognising that the ester linkage would be hydrolysed. Many candidates appreciated that the vinegar would degrade the packaging material but did not specify how it was achieved.
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- (i) A good number of candidates correctly showed a displayed ester linkage but gave structures which showed an extra oxygen atom in their repeat unit, gaining no credit.
 - (ii) This question proved difficult for many candidates who could not relate the structure to the intermolecular forces between the chains and did not indicate the groups involved. Hydrogen bonding was a common error.
 - (iii) Many candidates successfully gave a correct answer here, e.g. the co-polymer would have a higher melting point.

CHEMISTRY

Paper 9701/43

A2 Structured Questions

Key Messages

Candidates should be reminded to use the correct number of significant figures during and at the end of a calculation.

Candidates need to read the questions carefully before answering them. Questions where this was noticed were:

Question 1(b)(ii) - candidates did not write an **ionic** equation, with **state symbols**,

Question 4(c) - candidates mis-read reaction 2 as being the oxidation of **B** to **A** rather than the reduction of **A** to **B**,

Questions 4(a) and 4(d) - candidates gave the formulae rather than the names of functional groups,

Question 7(a)(i) - candidates forgot to include hydrogen atoms in their answer.

Candidates from some Centres also showed little understanding of reaction pathway diagrams in their answers to **Question 2(c)**. Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly in organic chemistry.

Candidates need more practice in the interpretation of NMR spectra; splitting patterns were frequently not mentioned and when they were, their significance was often misinterpreted in determining the structure of a compound. Chemical shift values were sometimes interpreted too literally.

General Comments

There was no general evidence of candidates' running out of time. The answers to the 'Applications' questions in **Section B** were generally of a higher standard than previously, and the overall neatness and legibility of answers was good. This was not always the case, however and candidates are reminded to make sure that their desired final answers are obvious to the Examiner and legible.

This report should be read in conjunction with the published mark scheme for this paper, which offers accepted answers to the questions.

Comments on Specific Questions

Section A

Question 1

(a) Most candidates incorrectly stated that magnesium chloride reacted with water to give a white precipitate of $\text{Mg}(\text{OH})_2$ or MgO . Others thought that aluminium chloride just dissolved, without the partial hydrolysis that produces $[\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}^+(\text{aq})$.

(b)

(i) A common error here was to assume that the 2.0 g was the mass of Cl , and thus calculated the moles of Cl incorrectly. Others assumed a 50:50 mixture of NaCl and KCl , or only used one of the two chlorides in their calculation.

(ii) Most candidates wrote the full 'molecular' equation here instead of the ionic equation. Some expanded the full equation into the constituent ions, but did no cancelling of the $\text{Na}^+(\text{aq})$ and $\text{NO}_3^-(\text{aq})$, or did not appreciate that $\text{AgCl}(\text{s})$ is not separable into its ions.

- (iii) Many candidates scored well here, as credit for error carried forward was available for those who had miscalculated $n(\text{Cl})$ in (i).
- (c)
- (i) Some candidates chose to include **all** bonds in their calculation, even those bonds (the majority) that did not change during the reaction. Consequently wrong answers were often obtained, by not adding up the number of bonds correctly. Candidates should be aware that, in general, the same number of bonds are made as have been broken during a reaction. Quite a number of candidates forgot that a C–H bond had been broken in benzene during the reaction. Others thought that **two** I–I bonds were broken during the reaction.
- (ii) The balancing of the equation was well done by most candidates, and many also correctly described the changes in oxidation numbers.

Question 2

- (a) The meanings of these words were generally well-known, although some candidates did not specify that a catalyst *increases* the rate of a reaction, rather than just *affects* its rate. Others explained that an alternative pathway was offered, but did not state that it had a lower (activation) energy. Almost every candidate knew the meaning of the term *homogeneous*.
- (b)
- (i) Most knew that either lightning or the burning of fossil fuels were common sources of atmospheric nitrogen oxides. Quite a number of candidates did not explain adequately how NO_x is formed, however: 'nitrogen is oxidised' was not sufficient - the participation of atmospheric oxygen, O_2 , needed to be stated.
- (ii) Most candidates knew that a major component of acid rain is H_2SO_4 , but fewer were able to write complete equations showing the catalytic roles of NO and NO_2 in the oxidation of SO_2 to SO_3 .
- (c) It was surprising how few candidates gained credit in this part. There were many diagrams that showed an endothermic reaction, or (the most common error) that showed the ΔH as being the difference in energy between the products and the energy hump maximum, rather than the reactants. Few showed a diagram with two humps: one for the un-catalysed, and a lower one for the catalysed reaction, and even if this were the case, usually only one activation energy was shown and labelled. Some candidates drew superb diagrams, however, even showing a high-energy intermediate in the case of the catalysed reaction.

Question 3

- (a) This was well answered by the vast majority of candidates. The most common errors were to state the configuration as $\dots 3d^7 4s^2$ or $3d^8 4s^1$. Some gave the configuration of the Cu atom; $3d^{10} 4s^1$.
- (b)
- (i) Only a few candidates gained full credit here. Most did not mention that the electrons in the d-orbitals pointing towards the ligands are *repelled* by the ligand lone pairs, and so are at higher energy.
- (ii) This part was much better known: most pointed out that when a photon of light is absorbed by an atom, an electron within it is promoted to a higher orbital. The number of candidates who incorrectly explained the colour by the emission of light as the electron falls back down again was pleasingly fewer than in previous years. However, there was a significant number of candidates who attributed the actual splitting of the d-orbitals to the incident light photon.
- (iii) The key to this colour dependence is the fact that different ligands produce different sizes of energy gap between the two sets of d-orbitals. This was not clearly stated by several candidates.

- (c) Many candidates performed well on this part. The most common errors were to use an iron electrode in the $\text{Fe}^{2+}/\text{Fe}^{3+}$ half of the cell, or to include in the circuit a power pack or battery rather than a voltmeter. Most remembered to include a salt bridge, but some did not specify that in order to measure the *standard* potential, E^\ominus_{cell} , the solutions had to be at 1.0 mol dm^{-3} and 298K .
- (d) This part could have been answered either in terms of the precipitation of $\text{Cu}(\text{OH})_2$ or in terms of the formation of the $[\text{Cu}(\text{NH}_3)_4]^{2+}$ complex. Either was acceptable, and both were seen. Answers had to be consistent, however. Most candidates gained credit for (i) and (iii), but many did not write a correct balanced equation in (ii). In (iv) candidates could have answered either in terms of le Chatelier's principle or by using E^\ominus values from the *Data Booklet*.
- (e)
- (i) Almost all candidates correctly identified the functional group as aldehyde.
 - (ii) In contrast, very few gained credit here. The most common errors were to describe an *orange* solid, or a silver mirror or a red *solution* rather than a red solid.
 - (iii) Very few candidates knew that the red precipitate is copper(I) oxide. Those that did, often wrote an unbalanced equation, or one including H^+ on one side.
- (f) In general this part was answered well, with the majority of candidates gaining full credit. The most common error was to invert the salt/acid ratio.

Question 4

Only the most able candidates deduced the correct structure of curcumin, but nevertheless there were many who scored highly on this question, correctly working out structures for the compounds **A – D**, and identifying the correct functional groups from the reactions described.

- (a)
- (i) Most candidates identified 'carbonyl'. Some, however, incorrectly specified 'aldehyde', for which no evidence had been given in the question. Curcumin itself might have contained an aldehyde group (see (e)), but neither **A** nor **D** could have such a group.
 - (ii) Several candidates drew the formula $-\text{COOH}$, rather than giving its name, as the question asked. Others incorrectly described the functional group as 'carboxyl' rather than 'carboxylic acid'. The carboxyl group, $-\text{CO}_2^-$, occurs in esters as well as in carboxylic acids.
- (b)
- (i) Most candidates correctly identified compounds **B** and **C**, but fewer drew the correct structure for **D**. The most common error was to draw the aldehyde, $\text{aryl}-\text{CH}_2\text{CHO}$, rather than the methyl ketone, $\text{aryl}-\text{COCH}_3$, perhaps confusing the iodoform test with one of the tests for the CHO group. Candidates who chose to write the formulae with a functional group ($-\text{CN}$ or $-\text{CO}_2\text{H}$) on the left hand side of the structure need to remember to show the correct atom connections. Thus $\text{NCCH}(\text{OH})\text{CH}_2\text{CH}(\text{OH})\text{CN}$ is the formula for **C**, whereas $\text{CNCH}(\text{OH})\text{CH}_2\text{CH}(\text{OH})\text{CN}$ represents a different compound, the isocyanide.
 - (ii) Most candidates gained credit here, although some omitted 'heat' or 'aqueous' with their acid (H_2SO_4 or HCl).
- (c)
- (i) Some candidates mis-read the chart, and thought that the reaction 2 arrow went from **B** to **A** and not vice versa. Although 'reduction' was the expected response, 'nucleophilic addition' or 'hydrogenation' was accepted if it was appropriate to the reagent specified in (ii).
 - (ii) The most common answer was either NaBH_4 or LiAlH_4 , although some candidates used $\text{H}_2 + \text{Ni}$ as the reagent.
 - (iii) Quite a number of candidates decided to change the order of functional groups along the chain, for either compound **A** or compound **B** or both. Thus $\text{HO}_2\text{CCOCOCH}_2\text{CO}_2\text{H}$ was sometimes offered as a structure for **A**.

- (d)
- (i) Despite the word **Name** being in bold type, there was a significant number of candidates who used the formula instead. 'Alkene' or 'C-C double bond' was required.
 - (ii) There were many candidates who named one of the functional groups as 'benzene' or 'aryl' or 'phenyl', rather than 'phenol'.
- (e) Two structures fitted with the information given: that of curcumin itself, and an isomer. The methoxy group was unfamiliar to candidates, and so errors in the drawing of it were ignored.

Question 5

- (a)
- (i) Several candidates chose to answer the question 'How is ethylamine basic?', rather than 'Why is it basic?', and thus described its reaction with acids, rather than explaining that the lone pair on the nitrogen atom was the key.
 - (ii) Most gave an acceptable equation showing ethylamine reacting with H^+ or HCl etc., but some did not balance it. Only a minority of candidates gained credit for the second equation, however: the reaction of ethylamine with either a halogenoalkane or an acyl halide was required.
 - (iii) Many candidates recognised that the delocalisation of the lone pair over the ring would reduce its availability for reaction with a proton.
 - (iv) Quite a number of candidates did not interpret this as a simple acid-base reaction, and suggested formulae that incorporated chlorine atoms - sometimes breaking the ring bonds too. Those who did recognise that one or more of the nitrogen atoms would be protonated sometimes did not show the positive charge on the nitrogen atom. Only the very able candidates realised that the pyridine nitrogen could also be protonated, and received credit for this.
- (b)
- (i) There were many good answers to this part, although quite a number of candidates confused $NaNO_2$ and $NaNO_3$, or HNO_2 and HNO_3 . Most quoted an acceptable temperature, $< 10^\circ C$, but some incorrectly suggested *refluxing* the solution at $5^\circ C$.
 - (ii) These four formulae were usually drawn correctly. Some candidates included an $-NH_2$ group on *both* of the rings to be coupled; others did not appreciate the significance of the given examples, and included the $-NH_2$ on the wrong ring.
 - (iii) The effect of including an ionic group on the properties of methyl orange was described well by the more able candidates.

Section B

Question 6

This was one of the best answered questions on this paper, especially for the weaker candidates.

- (a) The key significance of the achirality of glycine was not appreciated by the majority of candidates.
- (b) This was generally very well answered.
- (i) Some candidates suggested a double helix rather than an α -helix, or β -pleat rather than β -sheet.
 - (ii) Most candidates chose two appropriate bonding examples. The most popular amino acids used to illustrate these were alanine, glycine, cysteine and serine, although sometimes the amino acid did not correspond to the bonding (e.g. alanine was used to illustrate ionic or hydrogen bonding).

- (c) The key to this part was to recognise the different properties globular proteins or enzymes must have, when compared to a more hydrophobic alanine-and-glycine-containing protein such as spider silk. Hydrogen bonding or ionic groups would enhance the solubility of globular proteins, and would also be necessary as constituents of the active sites of enzymes. Only the more able candidates recognised these points.
- (d) This was a very straightforward part, and most candidates gained full credit.
- (i) A very few candidates mixed up the bases, and suggested A–C and G–T as the pairs.
 - (ii) Either a pentapeptide, or a hexapeptide (including *met* at the start) was accepted for the sequence. Many candidates also included ‘-stop’ in their answer, despite it not being part of the amino acid sequence the question asked for.
 - (iii) Almost all candidates gained credit here.

Question 7

- (a)
- (i) Candidates showed a good understanding of how to calculate the number of carbon atoms from the mass spectrum peak height ratio, but far fewer deduced from the NMR spectrum that **J** contained 10 hydrogen atoms.
 - (ii) Most used the M_r value to decide that oxygen was the third element. Some suggested nitrogen, bromine or chlorine, however.
 - (iii) The most common incorrect response was to suggest that **J** was the methyl ketone $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$, possibly because the δ value of 2.4–2.5 was close to that given for COCH_3 in the *Data Booklet*. The splitting pattern, so characteristic of the ethyl group, was ignored. Candidates should be aware that δ values need to be interpreted broadly, and that the list given in the *Data Booklet* cannot possibly include every molecular environment.
- (b)
- (i) The majority of candidates gave the correct responses here. Some, however, described instead the nature of the chromatography.

The remainder of the question was very well answered by the majority of candidates, although a few seemed to have read the chromatogram the wrong way round, with solvent 1 going from left to right, and solvent 2 going from bottom to top. Most candidates circled only one spot in (iii), but those who changed their minds needed to make it very clear as to which spot they meant the Examiner to take as their answer.

Question 8

- (a) This part was well answered by the vast majority of candidates. Those not gaining full credit either showed a repeat group rather than a monomer, or mixed up the addition-condensation description of reaction type. Either acids or acyl chloride were accepted for the relevant monomers.
- (b)
- (i) Candidates needed to think about the meaning of density and suggest a reason why the volume-per-gram of **B** would be less than that of **A**. The distance between the chains, or the compactness of the packing, was the important feature. **A** would have greater inter-chain forces due to hydrogen bonding, as compared to the weaker van der Waals bonding in **B**, and hence its chains might be closer together. Chains of **B** might also be held further apart by the methyl side-groups, which are absent in **A**. Some candidates attempted to answer in terms of the two monomers of **A** having a joint M_r greater than that of the monomer of **B**, or the monomers of **A** containing heavier atoms such as N or O.
 - (ii) Most candidates appreciated that the chains of polymer **B** would have the weakest van der Waals forces between them.

CHEMISTRY

Paper 9701/51

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Where details of the hazards associated with the use of particular chemicals are provided, it is expected that these will be used to answer questions asking how to minimise the risks associated with their use.

General Comments

Questions may sometimes ask for an understanding of the procedure required for an experiment with which candidates are unfamiliar. This occurred for many in **Question 1**. In these cases the marking scheme will allow considerable leeway covering realistic procedures suggested by candidates. However candidates must think carefully about the essential practicality of what they describe. Descriptions and associated diagrams must take account of any safety precautions that are required and include apparatus that might reasonably be available in a laboratory. Note must be taken of any guidance points provided in the question.

When graphs are drawn, many errors would be avoided if candidates chose scales which were easy to use. Although it is important that the grid provided should be used fully, it is not necessary to cover the full area if this would involve the use of a scale that is difficult to read. Credit will be awarded if the plotted points cover at least half the grid in both directions. A check should be made that the scales used are linear throughout their range as an error could make subsequent questions based on the graph drawn difficult or impossible to answer.

Candidates should appreciate that a point that lies only very marginally away from a line of best fit should not be considered as anomalous. Some judgement is perhaps required but an anomalous point should be quite clearly distant from its expected position on the line.

Comments on Specific Questions

Question 1

- (a) This was meant to provide an easy starter to the paper so it was disappointing that many candidates did not gain credit here. Many confused molecules with atoms and gave answers which were half the correct values while others quoted the numbers from equations for the reactions of lead with oxygen. Even those who correctly gave the numbers of atoms in PbO and PbO₂ struggled with Pb₃O₄.
- (b) Most candidates gained at least partial credit here. It was often necessary to allow errors carried forward from (a). The axes were specified as 'moles of oxygen' and 'moles of lead' but a common error was to label the latter as 'moles of lead oxide'.
- (c) A wide range of possible answers was accepted here. Although there was no penalty, the words 'mass' or 'moles' were frequently missing from the answers which in other contexts might have been penalised. The most common error was to give hydrogen as the dependent variable.

- (d) It was clear that only a few candidates were familiar with the experiment they were asked to plan and it is worth adding that, as proposed, the experiment could not be safely performed in a laboratory unless a continuous supply of hydrogen could be guaranteed and any excess carefully burned off. Nevertheless, given the flexibility of the mark scheme, the general standard of responses was disappointing.

Many were unable to provide a suitable means of preparing hydrogen. The preferred answer was to use a moderately reactive metal and either dilute hydrochloric or dilute sulfuric acid but credit was awarded for other methods if they were reliable and safe. Sodium with water is unsafe but calcium and water and sodium with ethanol were both credited. Suitable electrolysis was also allowed. Methods involving the cracking of hydrocarbons or the manipulating of the Haber ammonia equilibrium are clearly inappropriate but were quite frequently mentioned. Credit could be obtained for a diagram showing hydrogen being passed over heated lead oxide with a suitable outlet but too many tried to force hydrogen into an enclosed container. Very few knew that burning off excess hydrogen is the best way of disposing of it but credit was awarded if the excess was collected over water or in a syringe.

- (e) It must be emphasised that the guidance statements (i) to (iv) in the stem of the question should give candidates a guide to where credit was available. However, many candidates ignored them, even to the extent of not stating a suitable mass for the lead oxide. Those who did suggest a mass did not always understand that very low masses would introduce sizeable percentage errors while very high masses could not possibly be accommodated in the apparatus suggested. Heating to constant mass was known by a reasonable number of candidates, as was the calculation of the minimum volume of hydrogen. A clear description of the processing of the results to obtain the formula of the lead oxide was poorly done or simply forgotten in the accounts given.

A number of candidates thought that oxygen would be released when the reaction took place and this led to considerable confusion when handling the results of the experiment.

- (f) Candidates should understand that simply suggesting the use of gloves and goggles does not address a question asking for the identification of a hazard and a method of minimising the risk it poses. The introduction to **Question 1** gave the answer that was required and candidates simply needed to copy the information provided. Other answers were accepted but if hot apparatus is mentioned the exact piece of equipment should be specified and heat-resistant gloves – not just gloves – are required as the precaution.
- (g) This question was generally quite well answered and most candidates gained at least partial credit. Columns that were not relevant or required were ignored by the Examiners but the presence of some of these headings made it clear that many candidates neither understand the experiment nor how to interpret the results obtained.

Question 2

- (a) It was intended that the two columns C and D would allow candidates to calculate firstly the value of $(a-x)$ and then $\log(a-x)$. Credit was awarded for the correct heading and values of the $\log(a-x)$ column only. Many candidates did this successfully but others did not realise that the \log expression did not have units. Errors in the use of significant figures were also quite common.
- (b) Many accurate graphs were drawn, receiving full credit. Common errors were the incorrect labelling of the axes, minutes becoming seconds for example, or the use of non-linear scales. The unnecessary use of obscure scales proved a source of difficulty for some. The best-fit line had to reach the origin to be acceptable and candidates should be careful to use a sharp pencil and a ruler of sufficient length to give a line with no visible join in it.
- (c) Even the most able candidates found this question demanding. Nearly all candidates could identify the anomalous points but possible reasons for these anomalies were rarely identified correctly. Some did understand that the anomalies might be the consequence of incorrect timing but then found it difficult to express themselves clearly enough to achieve credit.
- (d) This is a standard question and there were many good answers but still some candidates simply referred to the line being straight without any mention of the plotted points.

- (e) The construction lines for the determination of the gradient were usually drawn although many were too faint and thus hard to see against the background of the grid. The points too were often read correctly with only those who had chosen difficult scales having much difficulty. However the subsequent calculation of the gradient was poorly completed.
- (f) The answer that a straight line through the origin is obtained was not provided by as many candidates as was expected. Many candidates put numbers into the equation and felt this was sufficient. It was acceptable to answer in this way but only if a minimum of calculations for two results was provided.
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Key Messages

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General Comments

This examination format differed from the usual in that it contained three questions which probably assisted candidates in their responses.

Question 1

This was usually answered reasonably well with many candidates gaining full credit.

Question 2

When questions ask for step by step descriptions of laboratory experiments candidates should focus on the specific points asked for in the stem of the question. Specific points were asked for in **Question 2(b)** but were often missing from candidates' explanations.

Question 3

This was a much different question from those in the past. The candidates responded well in calculating the data and the presentation of the graphs (given the difficulty in drawing curves) was quite good.

Comments on Specific Questions

Question 1

- (a) The question required a basic knowledge of the gas laws, in particular, Boyles Law giving the inverse relationship between volume and pressure. The correct response of a pressure increase with volume decrease was given by most, but not all, candidates. In many cases candidates had 'increase' crossed out and replaced by 'decrease' and vice versa, this sometimes being repeatedly done. The explanation usually correlated with the prediction. The question prompted the response to be in terms of an increased frequency of collisions rather than more collisions which was followed by most candidates.

The display of the prediction was more variable in response. Sketch graphs need the axes to be labelled which was done quite well. The plot of a curve or straight line of negative gradient, not touching either axis, was a common acceptable response. Some candidates gave a plot of P vs $1/V$ with a straight line starting at the origin which was also acceptable. Sometimes there were plots of P vs V with a straight line from the origin which contradicted the prediction. The intention of the second line was for one parallel to and higher than the first. A number of candidates essentially redrew the plot as pressure against temperature rather than another P vs V plot at an increased temperature.

- (b) The independent and dependent variables were correctly identified by the vast majority of the candidates.

Question 2

- (a) Most candidates scored well on the diagram for this experiment and a significant majority gained full credit. Some candidates' answers were incomplete in that they omitted the capacity of the gas collector. Others gave an impractical collector volume of many cubic decimetres. Some were over-elaborate in including ethanoic acid within the heated tube. A small number included a carbon dioxide absorber prior to the gas collector which would then not allow the volume of gas produced to be measured. It was pleasing to note that virtually all of the candidates realised that direct heating was required so very few indirect methods, such as water baths, were seen. The general impression of these responses was very good.
- (b) The format of this question provides a series of points which should be addressed in responding to the question. It was encouraging to see that an increasing number of candidates were accepting this provided lead and responding directly to those five. Those who responded with a generalised method invariably scored less well.

Of the five points, the first two calculations were reasonably well done, requiring the use of mole ratios between solids and gases along with molar volume to a gas volume. Sometimes an incorrect ratio was used in equation 2.1 leading to a double answer. The data of 24 dm^3 was sometimes taken to be 24 cm^3 or 2400 cm^3 .

In the third calculation it was necessary to calculate a mass of copper(II) carbonate that would produce a volume of gas that the collector would be capable of measuring. The collector volume given in (a) was allowed even if it was impractical. Often the calculation related to the mass of carbonate alone and did not relate to the volume of gas produced. Many calculations stopped at the molar mass of copper(II) carbonate.

The fourth marking point was most often credited. Often those candidates who chose a generalised description achieved this credit. It was necessary to respond with a clear experimental observation of the reaction end such as 'the syringe piston stops moving' rather than a deduction such as 'no more gas produced'. Reheating to constant mass is an inappropriate technique in this experimental context and a number of candidates referred to all of the solid turning black which is unrealistic to observe.

There were many ways that credit for the fifth marking point could be gained by using the mole ratios of materials to those in the equations but often this part of the question was not attempted. The most direct response would be to relate the ratio of moles of copper(II) carbonate used to the moles of gas produced. Alternatives were seen, such as 'If 1.0g were decomposed and 243 cm^3 gas was produced then equation 2.1 would be correct, or 194 cm^3 equation 2.2 would be correct'. A gradient value from a mole/mole plot of 1 would confirm equation 2.2 was another acceptable alternative. A number of candidates stated that equation 2.2 was correct without justifying their statement. There were a number of responses that were not related to the mole ratios of materials to those in the equations.

- (c) There was a variable response to the hazards involved in this experiment, often being incomplete. The most direct response was to take the provided hazard information as the response. Only a few adopted that approach. Often harmful was not coupled with the qualification of swallowing and the use of ethanoic acid in disposal was rarely mentioned. Often other hazards such as 'toxic' were given. Many settled for hot apparatus which also required the identification of which part of the apparatus was a heat hazard. In the hot reaction vessel hazard, the use of gloves needs the qualification of the gloves being heat resistant.

Question 3

- (a) Generally the table was completed very well. There was no requirement for column headings, formulas or units which made the task less complex. There were twelve values to calculate, some of which could be calculated in more than one way with sometimes a slightly different result (due to rounding to three decimal places in the density data). There was no direction as to the decimal place or significance required in the calculated data. As the data was presented to three decimal places it was reasonable to expect the candidates to follow that presentation and it was pleasing to see that virtually all candidates did so. It was not necessary to include trailing zeros in the calculated data. The item causing the most difficulty was the volume of sulfuric acid at 40%. There

was some evidence of truncating to three decimal places rather than correctly rounding e.g. the 50% value calculates to 1.28979 which some truncated to 1.289 rather than rounding to 1.290. A few candidates did not complete all of the twelve calculations.

- (b) The grid size for the plot was chosen so that the data would fit very well in portrait orientation. The bottom of the grid with ten large squares was a perfect fit for the independent variable (% by mass sulfuric acid) with its range from 0 to 100. Some candidates chose a half scale for this variable and some plotted it in landscape. The dependent variable, density, had a range that fitted the side axis well in ten large squares (each being 0.1 g cm^{-3}) given a false origin start at 0.9 g cm^{-3} . A few candidates started the density axis at 1.0 which then would not accommodate the first value of 0.997. A significant number of candidates chose to commence the density scale at zero which led to a half scale (one large square being 0.2 g cm^{-3}) which unsatisfactorily compacted the plot into less than half the available grid. The labelling of the axes along with units was very well done. There were many less inconvenient scales (such as one large square being 0.09 g cm^{-3}) than in previous years. There were very few plots with inverted variables. Candidates need to be advised that their scales should be in simple factors of ten and at least half of the grid is to be used in plotting.

Generally the plotting of the twenty data points was well done. The percentage by mass sulfuric acid values needed to be on the correct grid line with no tolerance. The allowed tolerance of \pm half a small square in plotting density permitted some range in the plotting of the density which operated to the candidates' benefit. One common mis-plot was to plot the first value as 0.0997 rather than 0.997.

The drawing of the two curves posed problems for the candidates. The two curves needed to be continuous and smooth. Many of the lines showed discontinuities at points, double lines, missed correctly plotted points and had points of inflexion (as wobbles) between points. Some had one or more 'straight' sections and others not completing the upper line over to the final 1.826 value. If mis-plots were present, some candidates deviated their lines to accommodate them rather than a best fit. Some lines were not labelled or had the labelling reversed.

- (c) Most candidates (with or without) construction lines correctly read density values at 45% and gained values of around 1.25 and 1.34 g cm^{-3} . However, the question required the difference, not merely the values, and a statement that the measured value was the higher. A common omission was the lack of a unit in the difference.

Very few candidates had reasonable suggestions for the difference in density. Whilst many realised and stated that there was hydrogen bonding in water, few gave the same for sulfuric acid, even stating its intermolecular forces of attraction were van der Waals forces or that (pure) sulfuric acid was ionic. The mixing of the two liquids producing changes in the amount and/or strength of hydrogen bonding or intermolecular forces of attraction was rarely seen. More often seen was that the sulfuric acid dissociated into ions in water which was an acceptable response to the second part.

- (d) This proved to be the most difficult question for the candidates to answer and most candidates had difficulty in finding a reasonable approach. A number of candidates attempted a calculation involving density being equated to mass/volume but this resulted in the mass and volume quantities becoming quite complex.
- (e) The expected response required a percentage error calculation in both cases. In the case of volume, 100 g of sulfuric acid was assumed to be 100 cm^3 whereas use of the table shows that 100 g of sulfuric acid has a volume of 54.765 cm^3 .