

CHEMISTRY

Paper 9701/11
Multiple Choice

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

This examination paper provided a challenge to many 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 2, 5, 14, 18 and 20**.

Nine questions were found to be particularly difficult. 25% or less of candidates chose the correct responses to each of **Questions 7, 11, 23, 26, 28, 29, 35, 36 and 38**. It should be noted that five of these questions are from the area of organic chemistry. These questions will now be looked at in greater detail.

Comments on Specific Questions

Question 7

18% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was B. 39% of candidates chose this answer. The choice of B may arise from a judgement based on the two-dimensional diagram on the paper. The question had to be answered by correctly judging the angles in the three-dimensional molecule, based on electron-pair repulsions.

Question 11

21% of candidates chose the correct answer, C. The most commonly chosen incorrect answers were B and D. 32% of candidates chose each of these answers. In each case the error here involves believing that atomisation involves the breakage of one mole of iodine molecules, rather than formation of one mole of iodine atoms.

Question 23

24% of candidates chose the correct answer, B. The most commonly chosen incorrect answer was D chosen by 34% of candidates. This arises from believing the second step is an oxidation; in fact it is a hydrolysis.

Question 26

24% of candidates chose the correct answer, D. The most commonly chosen incorrect answer was B, chosen by 39% of candidates. The lactic acid molecule has no aldehyde group so it will not react with Fehling's reagent, but it does have a carboxylic acid group and an alcohol group, so it can form an ester in the presence of a strong acid.

Question 28

21% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was A, chosen by 34% of candidates. The question depends on the knowledge that tertiary alkyl halides – such as C – will undergo an S_N1 substitution reaction.

Question 29

16% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was B, chosen by 42% of candidates. This is a difficult question, candidates who chose B may have realised that but-1-ene and but-2-ene are isomers of C_4H_8 , but may not have taken into account the *cis* and *trans* isomers of but-2-ene.

Question 35

13% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, chosen by 45% of candidates. The difference between A and B lies with statement 3. Statement 3 is true, as the only way the equation can be balanced is with HNO_2 .

Question 36

24% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was C, chosen by 37% of candidates. The difference between A and C lies with statement 1. Statement 1 is true. Element X is sulfur, Y is therefore SO_2 , which has lone pairs.

Question 38

18% of candidates chose the correct answer, B. The most commonly chosen incorrect answer was C, chosen by 39% of candidates. This means that statement 3 was believed to be true, but if Tollens' reagent is used the middle carbon atom will remain chiral, as it will be joined to four different groups, $-CH_2OH$, $-H$, $-OH$, and $-COO^-$, so statement 3 is false. Statement 1 is true, warmed acidified $K_2Cr_2O_7$ will oxidise the secondary alcohol to a ketone, so the middle carbon atom is no longer chiral.

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Paper 9701/12
Multiple Choice

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

This examination paper provided a challenge to many candidates. Seven questions can be said to have been found to be easier. 60% or more of candidates chose the correct responses to each of **Questions 1, 2, 6, 9, 16, 17** and **21**. None of **Questions 31-40** are on this list, suggesting that candidates still find this style of question challenging.

Seven questions were found to be particularly difficult. 30% or less of candidates chose the correct responses to each of **Questions 8, 12, 20, 25, 27, 39** and **40**. It should be noted that four of these questions are from the area of organic chemistry. These questions will now be looked at in greater detail.

Comments on Specific Questions

Question 8

28% of candidates chose the correct answer, D. The most commonly chosen incorrect answer was A, chosen by 48% of candidates. This answer, $-1388 \text{ kJ mol}^{-1}$, arose from the use of the data in the question

only. The question clearly instructs candidates to use the Data Booklet, as ionisation energies of calcium must be used.

Question 12

24% of candidates chose the correct answer, D. The most commonly chosen incorrect answer was C, chosen by 35% of candidates. This suggests that candidates knew that SrCO_3 would decompose at a higher temperature than MgCO_3 , but did not realise that Sr(OH)_2 is more soluble than Mg(OH)_2 and therefore produces a solution of higher pH.

Question 20

24% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was A, chosen by 33% of candidates. 27% of candidates chose B. Therefore the majority of candidates decided that $\text{C}_3\text{H}_3\text{Cl}_3$ has less than five structural isomers. It is difficult to suggest the reason for this with any certainty, unless they did not draw the isomers out during the exam.

Question 25

23% of candidates chose the correct answer, D. The most commonly chosen incorrect answer was C, chosen by 42% of candidates. This question relates to some standard practical chemistry. The correct answer, reaction D, occurs almost instantly at room temperature, while reaction C is comparatively very slow even when boiled under reflux.

Question 27

22% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, chosen by 38% of candidates. Choice B may be chosen because the hydrolysis of the ester under these conditions is not appreciated. Choice D was chosen by 22% of candidates, who mistakenly thought that the reactions given would add H_2O to the alkene groups.

Question 39

21% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was D, 30% of candidates chose this answer, although answers B and C were both also chosen by over 20% of candidates. The statistics suggest that many of the candidates who did poorly overall may have guessed on this question. The question depends on correctly known molecular formulae followed by a calculation based on M_r values and percentages, and this obviously proved very difficult for some.

Question 40

19% of candidates chose the correct answer, D. The most commonly chosen incorrect answer was B, chosen by 38% of candidates, although answers A and C were also chosen by over 20% of candidates. The question depends on an understanding of the $\text{S}_{\text{N}}1$ reaction mechanism. The hydrolysis of a tertiary alkyl halide, e.g. $(\text{CH}_3)_3\text{CBr}$, goes via a two-step $\text{S}_{\text{N}}1$ reaction mechanism which fits the reaction pathway here, so choice 1 is correct. The hydrolysis of a primary alkyl halide, e.g. $\text{CH}_3\text{CH}_2\text{Br}$, goes via a one-step $\text{S}_{\text{N}}2$ reaction mechanism which does not fit the reaction pathway here, so choices 2 and 3 are incorrect.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

This examination paper provided a challenge to many candidates. There were a significant number of excellent performances. Eleven questions can be said to have been found to be easier. 70% or more of candidates chose the correct responses to each of **Questions 1, 2, 3, 5, 7, 8, 14, 17, 19, 21 and 23**.

Seven questions were found to be particularly difficult. 45% or less of candidates chose the correct responses to each of **Questions 6, 28, 29, 31, 32, 34 and 40**.

None of **Questions 31-40** are on the list of questions that were found easier, while four of them are on the list of questions that were found harder. This suggests that candidates still find this style of question challenging.

The questions that were found to be particularly difficult will now be looked at in greater detail.

Comments on Specific Questions

Question 6

28% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was A, chosen by 35% of candidates. The choice of A may arise from a judgement based on the two-dimensional diagram on the paper. The question had to be answered by correctly judging the angles in the three-dimensional molecule, based on electron-pair repulsions.

Question 28

44% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was A, chosen by 24% of candidates. The question depends on the knowledge that tertiary alkyl halides – such as C – will undergo an S_N1 substitution reaction.

Question 29

37% of candidates chose the correct answer, C. The most commonly chosen incorrect answer was B, chosen by 37% of candidates. This is a difficult question, candidates who chose B may have realised that but-1-ene and but-2-ene are isomers of C_4H_8 , but may not have taken into account the *cis* and *trans* isomers of but-2-ene.

Question 31

30% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, chosen by 44% of candidates. Answers A and B depend on the accuracy of statement 1. Candidates who chose B may not have realised that molecules with $-NH_2$ groups have hydrogen bonding within their molecules, since the examples of hydrogen bonding that are most commonly encountered are those that involve $-OH$ groups.

Question 32

45% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, chosen by 28% of candidates. The question depends on three different areas of industrial chemistry – economics, application of Le Chatelier's principle, and reaction rate – and it may have been this diversity that some candidates found difficult.

Question 34

25% of candidates chose the correct answer, A. The most commonly chosen incorrect answer was B, chosen by 42% of candidates. The difference between A and B lies with statement 3. Statement 3 is true, as the only way the equation can be balanced is with HNO_2 .

Question 40

41% of candidates chose the correct answer, B. The most commonly chosen incorrect answer was C, chosen by 21% of candidates, while 19% chose A and 19% chose D. These statistics suggest that many candidates found all of statements 1, 2 and 3 difficult to evaluate correctly.

CHEMISTRY

Paper 9701/21
AS Structured Questions

General comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Chemistry syllabus. Overall, there were many good answers to the paper and most candidates were able to demonstrate some positive achievement.

Chemistry has a significant factual content and some of the questions asked candidates to recall their knowledge of the chemistry to be studied. There were many good answers to these questions but a number of candidates had not learned some basic chemistry. A large number of candidates struggled with one or both of the calculations, often because they did not use a logical method of answering the questions.

Comments on Specific Questions

Question 1

This question tested candidates' understanding of a familiar term used in chemistry and their ability to do a relatively simple calculation. While there were many good answers to each part, few candidates scored consistently well throughout the question.

- (a) Definitions in science must be accurate statements. It was apparent that many candidates understood what the term *molecular formula* means but were unable to express their answers unambiguously. The most common mistake was to discuss the ratio of numbers of atoms rather than the actual number of atoms of each element in a molecule.

There was a particularly large number of candidates who did not appreciate that the molecular formula refers to one molecule of a compound.

- (b) Many candidates struggled to balance the equation in terms of x and y .
- (c) There were many good responses to individual parts of this question but few candidates gave four correct answers.
- (i) The gas that remained after all of the reactions had been carried out was O_2 , although many candidates thought otherwise. Careful reading of the question should have suggested this in the reference to 50 cm^3 of O_2 (an excess).
- (ii) While many candidates correctly identified this gas as CO_2 , there was a significant number who thought it was water vapour.
- (iii) The CO_2 produced by the combustion of **A** was removed by the $KOH(aq)$, a process which reduced the total volume of gas by 10 cm^3 . Many candidates who gave a correct answer to (ii) were able to deduce this.
- (iv) The initial volume of O_2 used was 50 cm^3 and 30 cm^3 remained at the end of the experiment. The volume of O_2 used up was therefore 20 cm^3 . Many candidates were able to calculate this correctly.

- (d) Although a significant number of candidates struggled with this part of the question, there were many fully correct answers. Problems experienced by candidates were often caused by not using the equation they had given correctly in (b) or by not linking volumes of gas to numbers of molecules in their equation.

Question 2

Nitrogen is the major component of the Earth's atmosphere and a sound knowledge and clear understanding of the industrial and environmental importance of nitrogen and its compounds are an important aspect of AS level chemistry. There were many good answers to this question.

- (a) This was very well answered by the majority of candidates.
- (b) Most candidates knew the operating conditions of the Haber process. Fewer were able to explain the reasons why these conditions are used in the industrial process. This was particularly true when their effects on the position of equilibrium were discussed, few candidates using Le Chatelier's principle to explain the effect(s) being mentioned. For example, many candidates did not correctly refer to the link between the temperature they quoted and the exothermic nature of this reaction.
- (c) Most candidates gave a correct answer to this part.
- (d) While the majority of candidates knew that eutrophication involves the growth of algae and aquatic plants, fewer were able to explain clearly how this eventually affects the levels of dissolved oxygen in rivers and streams.
- (e)
- (i) The majority of candidates knew that CO is produced by the incomplete combustion of hydrocarbon fuels in an internal combustion engine. However, a significant number of candidates referred to the burning of carbon in an internal combustion engine, and often followed this with an equation showing the reaction of solid carbon with oxygen to form carbon monoxide. A surprising number of candidates thought that NO is produced in a similar manner in an internal combustion engine rather than by the reaction between the N_2 and O_2 of the air.
- (ii) Most candidates were able to identify a hazard associated with each gas.
- (f)
- (i) This was generally well answered.
- (ii) Only a minority of candidates was able to construct a correct equation for the reaction between CO and NO in a catalytic converter.

Question 3

Industrial processes involving crude oil are important in understanding how many of the simple compounds dealt with in organic chemistry are produced. Many candidates demonstrated a good knowledge of these processes. However, the structures of the isomers of pentane and the calculation at the end of the question caused problems for a significant number of candidates.

- (a)
- (i) Most candidates gave a clear and unambiguous answer to this question. The most common error was to describe a carbohydrate rather than a hydrocarbon. A small number of candidates thought that hydrocarbons are composed 'mainly of carbon and hydrogen'.
- (ii) This was slightly less well done with many candidates omitting to mention that in fractional distillation, compounds are separated *by boiling point*.
- (b) Most candidates knew that cracking is carried out by thermal or catalytic processes which require the use of high temperature, high pressure and a catalyst.
- (c)
- (i) While many candidates drew three correct structures, there was a large number who gave two structures and then repeated one of them. Candidates using the drawing notation which requires side-chain methyl groups to be placed in parentheses frequently omitted the brackets from the structure which they then regarded as a linear isomer e.g.

$\text{CH}_3\text{CH}_2\text{CHCH}_3\text{CH}_3$ should be drawn as $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$.

The use of simple molecular models in teaching enables candidates to gain an appreciation of the three-dimensional nature of molecular structures. Guidance about drawing structures of organic molecules is given in Section 10.1 of the syllabus.

- (ii) Many candidates struggled with this part. There were many who thought incorrectly that $\text{C}(\text{CH}_3)_4$ would have the highest boiling point because it appears to have the largest surface area. In fact the linear isomer pentane has the highest boiling point because of the ability of pentane molecules to pack closely together thus enabling stronger van der Waals' forces to be formed. There were also candidates who did not know which intermolecular forces of attraction are broken during boiling. Their answers frequently referred to 'bond breaking' occurring with reference to the covalent bonds within the molecule rather than the van der Waals' forces between them.
- (d) This was generally well answered although some candidates omitted to state that one mole of substance must be involved and that the combustion must be in an excess of air or oxygen. Those candidates who thought that combustion is an endothermic process by referring to the 'energy required' were not awarded full credit.
- (e) While many candidates were able to answer this correctly there was a significant number who experienced some difficulty with the problem.

Common mistakes in (i) were as follows;

- using a temperature rise of 300.5 K (i.e. $273 + 27.5$),
- using a mass of water of 0.47 g instead of 200 g,
- using a mass of water of $(200 + 0.47)$ g,
- using the gas constant instead of the specific heat capacity of water,
- using bond energies,
- using the numerical value of the specific heat capacity of water as 4.81 instead of 4.18.

A small number of candidates gave their answer in kJ when their calculation was in J or vice versa.

In (ii), many candidates omitted to use the value of 2059 kJ mol^{-1} given in the question.

- (f) From the relative molecular mass calculated in (e), the molecular formula of E is C_3H_6 .

Question 4

Knowledge of simple organic reactions is a requirement of the AS level Chemistry syllabus. There were many good answers to this question but a significant number of candidates struggled with different parts of it.

- (a) Most candidates knew the reagents but fewer knew the solvents that would be used.
- (b) This was generally well answered with many candidates correctly stating that 1-iodobutane would hydrolyse more quickly than 1-bromobutane. However, explanations were less well done and a significant number of candidates failed to quote relevant bond energy data from the *Data Booklet*, some referring to the bond energies of H-Br and of H-I rather than those of C-Br and C-I.
- (c) Relatively few candidates were able to give two correct statements.
- (d) As with candidates' answers to **Question 1(a)**, many candidates had a general understanding of the meaning of the term *homolytic fission* but were unable to describe it accurately.
- (i) The essential requirement for a good answer to this part was to refer to the splitting of a covalent bond and to explain that the two electrons of this covalent bond are shared between the two atoms involved.
- (ii) The equation to represent the homolytic fission of CCl_2F_2 was poorly answered. Many candidates introduced F_2 and Cl_2 molecules containing an unpaired electron, into their equations rather than simply forming a Cl radical and the CClF_2 radical.

- (e) A surprising number of candidates did not know that the major hazard of using hydrocarbons as aerosol propellants is their flammability.

Question 5

Few candidates gained full credit on this question. Candidates' performance on such questions can often be improved by greater experience of carrying out the practical procedure. The reactions between solid sodium halides and concentrated sulfuric acid are very easy to do and reveal much about the chemistry of the individual reactants.

- (a) The majority of candidates stated that NaBr was the salt concerned. Some candidates were clearly struggling however and gave ethanal as their answer. Presumably they were thinking of the orange compound formed when it reacts with 2,4-dinitrophenylhydrazine reagent.
- (b) Examiners accepted Br₂ or SO₂ as the gas produced but many candidates gave other compounds such as 'NaHSO₄' – which is not a gas.
- (c) Relatively few candidates were able to explain that concentrated sulfuric acid is a strong oxidising agent which will oxidise any HBr formed to Br₂ and be reduced to SO₂ at the same time. This piece of chemistry seems to be poorly understood by many candidates.

CHEMISTRY

<p>Paper 9701/22 AS Structured Questions</p>
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General comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Chemistry syllabus. Overall, there were many good answers to the paper and most candidates were able to demonstrate some positive achievement.

Chemistry has a significant factual content and some of the questions asked candidates to recall their knowledge of the chemistry to be studied. There were many good answers to these questions but a number of candidates had not learned some basic chemistry. A large number of candidates struggled with one or both of the calculations, often because they did not use a logical method of answering the questions.

Comments on Specific Questions

Question 1

This question tested candidates' understanding of a familiar term used in chemistry and their ability to do a relatively simple calculation. While there were many good answers to each part, few candidates scored consistently well throughout the question.

- (a) Definitions in science must be accurate statements. It was apparent that many candidates understood what the term *molecular formula* means but were unable to express their answers unambiguously. The most common mistake was to discuss the ratio of numbers of atoms rather than the actual number of atoms of each element in a molecule.

There was a particularly large number of candidates who did not appreciate that the molecular formula refers to one molecule of a compound.

- (b) Many candidates struggled to balance the equation in terms of x and y .
- (c) There were many good responses to individual parts of this question but few candidates gave four correct answers.
- (i) The gas that remained after all of the reactions had been carried out was O_2 , although many candidates thought otherwise. Careful reading of the question should have suggested this in the reference to 50 cm^3 of O_2 (an excess).
- (ii) While many candidates correctly identified this gas as CO_2 , there was a significant number who thought it was water vapour.
- (iii) The CO_2 produced by the combustion of **A** was removed by the $KOH(aq)$, a process which reduced the total volume of gas by 10 cm^3 . Many candidates who gave a correct answer to (ii) were able to deduce this.
- (iv) The initial volume of O_2 used was 50 cm^3 and 30 cm^3 remained at the end of the experiment. The volume of O_2 used up was therefore 20 cm^3 . Many candidates were able to calculate this correctly.

- (d) Although a significant number of candidates struggled with this part of the question, there were many fully correct answers. Problems experienced by candidates were often caused by not using the equation they had given correctly in (b) or by not linking volumes of gas to numbers of molecules in their equation.

Question 2

Nitrogen is the major component of the Earth's atmosphere and a sound knowledge and clear understanding of the industrial and environmental importance of nitrogen and its compounds are an important aspect of AS level chemistry. There were many good answers to this question.

- (a) This was very well answered by the majority of candidates.
- (b) Most candidates knew the operating conditions of the Haber process. Fewer were able to explain the reasons why these conditions are used in the industrial process. This was particularly true when their effects on the position of equilibrium were discussed, few candidates using Le Chatelier's principle to explain the effect(s) being mentioned. For example, many candidates did not correctly refer to the link between the temperature they quoted and the exothermic nature of this reaction.
- (c) Most candidates gave a correct answer to this part.
- (d) While the majority of candidates knew that eutrophication involves the growth of algae and aquatic plants, fewer were able to explain clearly how this eventually affects the levels of dissolved oxygen in rivers and streams.
- (e)
- (i) The majority of candidates knew that CO is produced by the incomplete combustion of hydrocarbon fuels in an internal combustion engine. However, a significant number of candidates referred to the burning of carbon in an internal combustion engine, and often followed this with an equation showing the reaction of solid carbon with oxygen to form carbon monoxide. A surprising number of candidates thought that NO is produced in a similar manner in an internal combustion engine rather than by the reaction between the N_2 and O_2 of the air.
 - (ii) Most candidates were able to identify a hazard associated with each gas.
- (f)
- (i) This was generally well answered.
 - (ii) Only a minority of candidates was able to construct a correct equation for the reaction between CO and NO in a catalytic converter.

Question 3

Industrial processes involving crude oil are important in understanding how many of the simple compounds dealt with in organic chemistry are produced. Many candidates demonstrated a good knowledge of these processes. However, the structures of the isomers of pentane and the calculation at the end of the question caused problems for a significant number of candidates.

- (a)
- (i) Most candidates gave a clear and unambiguous answer to this question. The most common error was to describe a carbohydrate rather than a hydrocarbon. A small number of candidates thought that hydrocarbons are composed 'mainly of carbon and hydrogen'.
 - (ii) This was slightly less well done with many candidates omitting to mention that in fractional distillation, compounds are separated *by boiling point*.
- (b) Most candidates knew that cracking is carried out by thermal or catalytic processes which require the use of high temperature, high pressure and a catalyst.
- (c)
- (i) While many candidates drew three correct structures, there was a large number who gave two structures and then repeated one of them. Candidates using the drawing notation which requires side-chain methyl groups to be placed in parentheses frequently omitted the brackets from the structure which they then regarded as a linear isomer e.g.

$\text{CH}_3\text{CH}_2\text{CHCH}_3\text{CH}_3$ should be drawn as $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$.

The use of simple molecular models in teaching enables candidates to gain an appreciation of the three-dimensional nature of molecular structures. Guidance about drawing structures of organic molecules is given in Section 10.1 of the syllabus.

- (ii) Many candidates struggled with this part. There were many who thought incorrectly that $\text{C}(\text{CH}_3)_4$ would have the highest boiling point because it appears to have the largest surface area. In fact the linear isomer pentane has the highest boiling point because of the ability of pentane molecules to pack closely together thus enabling stronger van der Waals' forces to be formed. There were also candidates who did not know which intermolecular forces of attraction are broken during boiling. Their answers frequently referred to 'bond breaking' occurring with reference to the covalent bonds within the molecule rather than the van der Waals' forces between them.
- (d) This was generally well answered although some candidates omitted to state that one mole of substance must be involved and that the combustion must be in an excess of air or oxygen. Those candidates who thought that combustion is an endothermic process by referring to the 'energy required' were not awarded full credit.
- (e) While many candidates were able to answer this correctly there was a significant number who experienced some difficulty with the problem.

Common mistakes in (i) were as follows;

- using a temperature rise of 300.5 K (i.e. $273 + 27.5$),
- using a mass of water of 0.47 g instead of 200 g,
- using a mass of water of $(200 + 0.47)$ g,
- using the gas constant instead of the specific heat capacity of water,
- using bond energies,
- using the numerical value of the specific heat capacity of water as 4.81 instead of 4.18.

A small number of candidates gave their answer in kJ when their calculation was in J or vice versa.

In (ii), many candidates omitted to use the value of 2059 kJ mol^{-1} given in the question.

- (f) From the relative molecular mass calculated in (e), the molecular formula of E is C_3H_6 .

Question 4

Knowledge of simple organic reactions is a requirement of the AS level Chemistry syllabus. There were many good answers to this question but a significant number of candidates struggled with different parts of it.

- (a) Most candidates knew the reagents but fewer knew the solvents that would be used.
- (b) This was generally well answered with many candidates correctly stating that 1-iodobutane would hydrolyse more quickly than 1-bromobutane. However, explanations were less well done and a significant number of candidates failed to quote relevant bond energy data from the *Data Booklet*, some referring to the bond energies of H-Br and of H-I rather than those of C-Br and C-I.
- (c) Relatively few candidates were able to give two correct statements.
- (d) As with candidates' answers to **Question 1(a)**, many candidates had a general understanding of the meaning of the term *homolytic fission* but were unable to describe it accurately.
- (i) The essential requirement for a good answer to this part was to refer to the splitting of a covalent bond and to explain that the two electrons of this covalent bond are shared between the two atoms involved.
- (ii) The equation to represent the homolytic fission of CCl_2F_2 was poorly answered. Many candidates introduced F_2 and Cl_2 molecules containing an unpaired electron, into their equations rather than simply forming a Cl radical and the CClF_2 radical.

- (e) A surprising number of candidates did not know that the major hazard of using hydrocarbons as aerosol propellants is their flammability.

Question 5

Few candidates gained full credit on this question. Candidates' performance on such questions can often be improved by greater experience of carrying out the practical procedure. The reactions between solid sodium halides and concentrated sulfuric acid are very easy to do and reveal much about the chemistry of the individual reactants.

- (a) The majority of candidates stated that NaBr was the salt concerned. Some candidates were clearly struggling however and gave ethanal as their answer. Presumably they were thinking of the orange compound formed when it reacts with 2,4-dinitrophenylhydrazine reagent.
- (b) Examiners accepted Br₂ or SO₂ as the gas produced but many candidates gave other compounds such as 'NaHSO₄' – which is not a gas.
- (c) Relatively few candidates were able to explain that concentrated sulfuric acid is a strong oxidising agent which will oxidise any HBr formed to Br₂ and be reduced to SO₂ at the same time. This piece of chemistry seems to be poorly understood by many candidates.

CHEMISTRY

Paper 9701/23

AS Structured Questions

General comments

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

Chemistry has a significant factual content and a number of questions asked candidates to recall their knowledge of the chemistry to be studied. There were many good answers to these questions but a number of candidates had not learned some basic chemistry.

The more able candidates scored well on **Question 3** which involved some unfamiliar compounds, while **Questions 1** and **5** provided many good answers for all candidates. **Questions 2** and **4** involved factual recall and benefited candidates who had concentrated on this aspect of their revision.

Comments on Specific Questions

Question 1

This question involved knowledge of atomic structure and basic calculations and provided high scoring answers for many candidates.

- (a) This was generally well answered. The correct phrase 'atoms of the same element with...' was often reduced to 'elements with...'.
- (b) This was well answered.
- (c) The majority of candidates calculated the A_r value correctly. The number of significant figures quoted in the candidates' answer should have been 4, the same as the data in the question. Information about significant figures and rounding up or down is given in Section 1(h) of the syllabus.
- (d) This was generally well answered, common errors being the use of $2Cl$, rather than Cl_2 , for chlorine or $MgCl$ for the product.
- (e) Correct answers of 0.020 mol of Sb reacting with 0.060 mol of Cl atoms to give **A** as $SbCl_3$ were common. There were some candidates who calculated the number of moles of Cl_2 molecules (2.12/71) rather than Cl atoms.
- (f) Interpretation of data is an important skill at AS and A level. In this part many candidates confused the forces or bonds that would be broken when the solid is melted.
- (i) Most candidates knew or deduced that $MgCl_2$ is an ionic solid.
- (ii) Fewer were able to deduce the bonding present in solid $SbCl_3$. This is a covalent solid. Many candidates were confused over the difference between these two.

Question 2

Much of this question involved factual recall of the chemistry of sulfur and its compounds.

- (a) Three equations were needed in the correct order starting from sulfur. The reactions were producing SO_2 from S and O_2 , producing SO_3 from SO_2 and O_2 (which is reversible) and, finally, forming H_2SO_4 from SO_3 and H_2O . Answers were generally correct with a small number of candidates writing unbalanced equations.
- (b) Examiners expected candidates to quote specific values of temperature and pressure rather than vague answers such as 'low temperature' or 'high pressure'. Acceptable values were 400 to 600 °C and 1 to 10 atm., with units given. The catalyst had to be specified as vanadium(V) oxide by name or formula.
- (c) The best answers were specific, such as "making fertilizers", and not vague such as "laboratory chemical".
- (d) (i) This was well answered.
(ii) The most common error in this part was giving the oxidation number of S in H_2S as +2. Most candidates realised the S in SO_2 was reduced as its oxidation number decreased in the reaction with H_2S .
- (e) (i) This was not well answered with many wrong equations involving nitric acid as a product.
(ii) The environmental effects of acid rain were well known.
- (f) The fact that SO_2 acts as a reducing agent in food preservation was known to about half the candidates.

Question 3

This question involved some unfamiliar organic compounds which required candidates to apply their basic knowledge to novel situations.

- (a) (i) Many candidates did not use the information given that C_2O has a carbon-carbon-oxygen sequence of atoms, and that one atom is surrounded by six electrons so producing a linear shape. As a result, many answers were wrong.
(ii) Many candidates clearly understood what a free radical is but were unable to express this in simple terms. Examiners expected reference to an atom or molecule which contains an unpaired electron.
(iii) The best answers to this part referred to the nitrogen atom forming two covalent bonds and having one lone pair so leaving an unpaired electron.
- (b) (i) The structural formula of the addition polymer was well answered, but some candidates still omit the bonds that link repeat units to one another and so cannot be awarded full credit.
(ii) The majority of candidates knew that this is an example of addition polymerisation.
- (c) (i) Compound **Z** must have the molecular formula $\text{C}_2\text{H}_4\text{O}$. Candidates had to realise **Z** was ethanal, CH_3CHO , and not to write it as CH_3COH .
(ii) The cyclic compound also has the molecular formula $\text{C}_2\text{H}_4\text{O}$ and candidates were expected to deduce that there would be a 3 atom ring.

- (d) The best answers came from those candidates who realised that Acrolein has two functional groups which can react independently of one another and who decided what each functional group did in the reactions given. The most common error was in the last reaction where many candidates thought NaBH_4 reduced both the $-\text{CHO}$ and the $>\text{C}=\text{C}<$ groups.

Question 4

This question dealt with reactions involving halogenoalkanes and received many good answers.

- (a) The majority of candidates were able to calculate the C:H:Br ratio as 3:7:1. The calculation to show that $M_r = 122.9$ was needed to prove that the empirical formula was the same as the molecular formula. Not all candidates did this.
- (b)
- (i) The best answers came from candidates who realised that the mechanism was $\text{S}_{\text{N}}2$ and so involved a 5-valent intermediate. The dipole on the C-Br bond was usually given but the attack of OH^- on the $\text{C}^{\delta+}$ atom often did not involve the lone pair of electrons on the O atom of OH^- . Most candidates completed their mechanism showing the Br^- leaving group.
 - (ii) This part required candidates to recall that $\text{C}_2\text{H}_5\text{Br}$ can give $\text{CH}_2=\text{CH}_2$ under different conditions. This was generally well answered.
 - (iii) Many candidates knew that ethanol is the solvent for this reaction.
 - (iv) The majority of candidates knew that this is an elimination reaction.
- (c)
- (i) Although many candidates knew that butan-1,4-diol would be formed a number failed to give the *displayed* formula as the question required.
 - (ii) Fewer candidates were able to deduce that buta-1,4-diene would be produced and only a minority of candidates gave one of the two *skeletal* formulae. Information about drawing different types of structural formulae is given in Section 10.1 of the syllabus.

Question 5

There were many high scoring answers here, with the majority of candidates showing a good knowledge of this reaction of halogenoalkanes.

- (a) This was generally well answered.
- (b) Most candidates knew this precipitate was white.
- (c) The iodo- compound was usually identified here.
- (d) The fact that the C-I bond is the weakest needed to be supported by evidence from the *Data Booklet* as required in the question. Therefore the bond energy of C-I at 240 kJ mol^{-1} had to be mentioned. Answers involving the bond length of C-I were acceptable but again data were needed from the *Data Booklet*.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

General comments

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If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and to a corresponding set of Supervisor results. Regrettably a number of Centres continue to provide no Supervisor information.

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

Some Centres do provide the Supervisor data for multiple sessions/laboratories but without seating plans or candidate lists and there is insufficient data to place candidates within each Session. Candidates in these Centres may again be disadvantaged. Where more than one session/laboratory is used, the candidates should be reminded to complete the boxes on the front page of their scripts with the relevant information.

There was little evidence of candidates failing to finish the paper in the allocated time although some weaker candidates left some sections blank.

Comments on Specific Questions

Question 1

The majority of candidates successfully performed the practical work in the question. The titration exercise set was capable of very reproducible results. The majority of candidates in Centres that were well prepared in titration techniques scored well for accuracy when compared to the Supervisor's titre. In some Centres the titres recorded by the candidates showed great variance with both the Supervisor titre and with the titres recorded by other candidates.

- (a) There was a change in the rubric for this paper – requesting candidates to record in a separate space the burette readings and titre value for a Rough titration. They were then asked to record data for accurate titrations in a subsequent space. Most candidates did as requested but some recorded all of their titration data in either the first or second of these spaces.

Most candidates recorded all of their accurate burette readings to the nearest 0.05 cm^3 as required. The Examiners note that the Rough titration is often also recorded to this degree of precision, which is not expected for a Rough titration.

A significant number of candidates did not record burette readings for the Rough titration.

Most candidates performed sufficient titrations to obtain at least two titres within 0.10 cm^3 .

- (b) Most candidates correctly derived a suitable titre value from their experimental work. Those who were not awarded credit here either did not show which values had been selected to obtain the

“mean”, included the Rough titre in the selected values, selected titres more than 0.20 cm³ apart or gave an answer with inappropriate significant figures.

- (c) As usual the calculation was set out step by step in the paper. The quality of answers seen ranged from every step correctly completed to little or no attempt at any of the sections. Common errors that were seen included the following.

Candidates not giving appropriate significant figures in each step of the calculation. This was most common in step (i) and in step (v). A number of candidates, who had given appropriate significant figures in the first four steps, gave the final answer to the calculation to just 1 significant figure.

Some candidates omitted the 5H₂O when calculating the *M_r* of sodium thiosulfate.

In step (iv) the ratio to be used was often incorrect, 6:1 and 6:5 being selected from the iodine containing compounds given in the equation.

- (d) For candidates with a good understanding of the maximum error involved when taking a single reading from a burette and the combined error when using the burette to measure a volume of liquid this section presented no difficulties. The maximum error in each reading of a burette was given as ±0.05 cm³. The maximum error when reading a volume of solution (two burette readings) was therefore ±0.10 cm³.

Many candidates gave ±0.05 cm³ as the answer to d(i). Other candidates added the given error for the single burette reading to the error given for the bulb pipette.

Credit was available for a correct answer in d(i) and (ii). There was therefore no credit for correctly calculating the % error (error carried forward) in d(ii).

Most candidates were able to calculate the % error when 25.0 cm³ was measured using a pipette. As many candidates had failed to double the reading error in d(i), the correct answer may well have been achieved in d(iii) without appreciating that measuring a volume with a pipette involves only one reading providing the pipette is then drained correctly.

Question 2

The majority of candidates successfully heated the basic copper(II) carbonate and obtained a mass of residue that produced good accuracy when compared to the results provided by the Supervisor. A number of Centres only provided Supervisor results for **Question 1** and not for **Question 2**.

If no Supervisor data was available for **Question 2**, the equation:

$$\frac{\text{mass of basic carbonate heated}}{\text{mass of residue}} = 1.45$$

was used as the standard for assessing accuracy. Candidates were not disadvantaged.

- (a) Most candidates recorded their experimental results clearly but many only recorded results for a single heating of the basic copper(II) carbonate. The rubric had requested that further heating, cooling and reweighing was carried out until satisfied that decomposition was complete.

Any evidence of reheating was rewarded if four appropriate balance readings were recorded (mass of empty tube, mass of tube + **FA 3** and two masses of tube + residue after heating). Further credit was available where there was evidence that the sample had been heated to “constant mass”. The concept of heating to constant mass did not appear to be understood by a large number of candidates.

Most candidates recorded balance readings with appropriate and consistent precision, but clear tabulation of each weighing, including its unit, was a skill still not possessed by many candidates. A small number of candidates incorrectly recorded the mass loss during the experiment as the mass of the residue and/or the mass of the residue as the mass loss in the experiment.

- (b) Most candidates correctly calculated the loss in mass as a percentage of the mass of solid heated.

- (c) This section was answered correctly by a very small number of candidates. The majority of candidates did not take note of the information given and assumed unjustified ratios other than 1:1 for copper(II) carbonate to copper(II) hydroxide, or that more than 1 mole of water was present in the basic copper(II) carbonate.

The Examiners were hoping to see a comparison of the M_r values to establish that there is a greater mass loss if more carbon dioxide and less water vapour are evolved. A calculated value greater than 33.5% therefore means there is a greater proportion of copper(II) carbonate to copper(II) hydroxide in the basic carbonate, or the reverse argument for a calculated percentage of less than 33.5%.

- (d) Most candidates were able to add to the diagram apparatus to collect and measure the volume of carbon dioxide evolved. The most appropriate piece of apparatus to use was a gas syringe and the majority of candidates used this. Collection of the gas over water in an inverted burette or measuring cylinder was also accepted, although the gas would have contained water vapour.

Removal of water vapour was often not attempted or an inappropriate method selected. Some candidates who used a condenser drew it in such a way that the water formed would flow into the gas syringe and be measured. Other candidates using a condenser left an open tube for the water to drain from the apparatus but still expected the carbon dioxide gas to push out the gas syringe or displace the water. Credit for suitable apparatus to collect and measure the volume of gas was still awarded in these cases.

A small number of candidates chose a suitable piece of apparatus/reagent to absorb the water vapour.

No penalty was applied for poor quality drawing of the diagram but the majority of diagrams seen could have been greatly improved upon.

Question 3

- (a) The four cations present, one in each of the solutions provided were given at the beginning of the question.

A table for recording observations with each of the specified reagents was provided.

Expected observations for the named ions with the reagents in the table were given in the Qualitative Analysis Notes on the question paper.

This part of the question should therefore have been much more straightforward than similar questions in past papers.

Many candidates gave complete and correct observations, scoring full credit for observation.

Despite the descriptions given in the Qualitative Analysis Notes the Examiners saw all too often a white precipitate described as a white solution or a cloudy solution. Candidates should be aware that the appearance of a white colour throughout the solution indicates the formation of a fine white precipitate that is held in suspension.

A number of candidates reported partial solubility of precipitates – a description that does not match any of the ion/reagent combinations in the Qualitative Analysis Notes.

Some candidates clearly muddled solutions when carrying out their tests.

Observations for **FA 6** and observations with aqueous potassium iodide represented the column and row observations respectively that were most often correct.

- (b) As the tests were considered to be very straightforward no error carried forward from observations was allowed in identifying the ions present. Candidates with correct observations in (a) had no difficulty in correctly identifying the ions present.

Some candidates introduced ions, other than the four given at the beginning of the question, when identifying the ions present.

Error carried forward was allowed in the supporting evidence provided there was no incorrect observation for the ions given. This enabled candidates who had used incorrect FA solutions or who had recorded observations under the incorrect FA identity to be awarded credit for conclusions.

Many candidates did not differentiate between aluminium and lead(II) in the supporting evidence given.

- (c) Most candidates suggested a suitable reagent to confirm the presence of lead(II) ions but some reused potassium iodide, others suggested lead(II) chloride.

Candidates should be reminded that a reagent is a compound – not a single ion. Hydrochloric acid or sodium chloride were suitable reagents but Cl^- was not allowed. The Examiners did accept $Cl^-(aq)$ on this occasion. Other suitable reagents were treated in a similar way.

- (d) Most candidates recorded an appropriate colour precipitate in (i) but the exothermic reaction – warming of the tube – was missed by the majority. Few candidates recorded that the blue colour of the solution faded, or that the blue solution turned colourless. Both the initial and the final colour of the solution were required for credit to be awarded.

Most candidates recorded a green solution in (ii) and a blue solution in (iii).

- (e) Many candidates correctly completed the equation together with appropriate state symbols but apart from those who omitted the state symbols some gave incorrect charges and others compounds involving copper and zinc or other elements that did not appear on the left hand side of the equation.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

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Most candidates recorded a green solution in (ii) and a blue solution in (iii).

- (e) Many candidates correctly completed the equation together with appropriate state symbols but apart from those who omitted the state symbols some gave incorrect charges and others compounds involving copper and zinc or other elements that did not appear on the left hand side of the equation.

CHEMISTRY

Paper 9701/34

Advanced Practical Skills 2

General comments

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There was little evidence of candidates not finishing the paper in the allocated time although some weaker candidates left some sections blank.

Comments on Specific Questions

Question 1

The majority of candidates successfully performed the practical work in the question. The titration exercise set was capable of very reproducible results. The majority of candidates in Centres that were well prepared in titration techniques scored well for accuracy when compared to the Supervisor's titre. In some Centres the titres recorded by the candidates showed great variance with both the Supervisor titre and with the titres recorded by other candidates.

- (a) There was a change in the rubric for this paper – requesting candidates to record in a separate space the burette readings and titre value for a Rough titration. They were then asked to record data for accurate titrations in a subsequent space. Most candidates did as requested but some recorded all of their titration data in either the first or second of these spaces.

Most candidates recorded all of their accurate burette readings to the nearest 0.05 cm^3 as required. The Examiners note that the Rough titration is often also recorded to this degree of precision, which is not expected for a Rough titration.

A significant number of candidates did not record burette readings for the Rough titration.

Most candidates performed sufficient titrations to obtain at least two titres within 0.10 cm^3 .

- (b) Most candidates correctly derived a suitable titre value from their experimental work. Those who did not gain credit here either did not show which values had been selected to obtain the "mean", included the Rough titre in the selected values, selected titres more than 0.20 cm^3 apart or gave an answer with inappropriate significant figures.

- (c) As usual the calculation was set out step by step in the paper. The quality of answers seen ranged from every step correctly completed to little or no attempt at any of the sections. Common errors that were seen included the following;
- Inappropriate significant figures in each step of the calculation.
 - In step (i) many candidates correctly calculated a concentration of 1.27 mol dm^{-3} but then gave the final answer as 0.01 mol dm^{-3} , introducing a 21% error in the calculated value.
 - A number of candidates, who had given appropriate significant figures in the first five steps of the calculation, gave the final answer to step (vi), the % of FeSO_4 in the mixture, to just 2 significant figures.
 - A number of candidates correctly calculated $\frac{2}{158}$ in step (i) but then multiplied by $\frac{\text{titre}}{1000}$ in the same step.
 - Some candidates used $S=32$ rather than the given $S=32.1$ when calculating the M_r of iron(II) sulfate.

Question 2

The majority of candidates successfully heated the mixture of sodium carbonate and sodium hydrogencarbonate and obtained a mass of residue that produced a good level of accuracy when compared with the standard value of 1.40 for the ratio, $\frac{\text{mass of mixture heated}}{\text{mass of residue}}$.

A number of Centres only provided Supervisor results for **Question 1** and not for **Question 2**.

- (a) Most candidates recorded their experimental results clearly but many only recorded results for a single heating of the mixture. The rubric had requested that further heating, cooling and reweighing was carried out until satisfied that decomposition was complete.

Any evidence of reheating was credited if four appropriate balance readings were recorded (mass of empty tube, mass of tube + **FB 3** and two masses of tube + residue after heating). Further credit was available where there was evidence that the sample had been heated to "constant mass". The concept of heating to constant mass did not appear to be understood by a large number of candidates.

Most candidates recorded balance readings with appropriate and consistent precision, but clear tabulation of each weighing, including its unit, was a skill still not possessed by many candidates. A small number of candidates incorrectly recorded the mass loss during the experiment as the mass of the residue and/or the mass of the residue as the mass loss in the experiment.

- (b)
- (i) Four errors were commonly seen in this section.
- The ratio was calculated using experimental values rather than data from the equation.
 - The stoichiometry of the equation was ignored and 84 rather than 168 was used as the mass of NaHCO_3 .
 - Candidates were careless in rounding when evaluating a correct expression.
 - No evaluation was attempted, the answer being left as a ratio.
- (ii) Credit was awarded in (b) for (i) and (ii). An incorrectly described mass loss in (a) was allowed in this section, error carried forward.
- (iii) Candidates were expected to consider their answer in (ii), tick the correct box in (iii) and provide justification for their choice. Credit was seldom awarded here.

Some candidates obtained a mass in (ii) that was greater than the mass of **FB 3** used. Credit was still available for stating that this was not possible but most candidates in this situation ticked one or other of the boxes and gave some other, incorrect answer.

Common errors seen in the justification included the following.

- The mass loss was equated to the mass of NaHCO_3 .
- Reference was made to Na_2CO_3 in the residue rather than Na_2CO_3 in the mixture.

- Candidates compared the experimental mass of residue with the mass of NaHCO_3 .
- (c) Few candidates gained full credit in this section. Credit was often awarded for reference to there being no loss in mass on heating sodium carbonate. Further credit was available for detecting no carbon dioxide, using limewater. Unfortunately candidates often referred to the gas evolved not turning limewater milky, which negated the statement, that there was no decomposition.
- (d) Candidates were reminded that errors in balance readings could be treated in the same way as burette readings and were told that the smallest division on a burette is 0.1 cm^3 and the maximum error in a single burette reading is $\pm 0.05 \text{ cm}^3$.

The Examiners therefore expected the maximum errors for a single balance reading to be
 $\pm 0.05 \text{ g}$ for a 1 decimal place balance,
 $\pm 0.005 \text{ g}$ for a 2 decimal place balance and
 $\pm 0.0005 \text{ g}$ for a 3 decimal place balance.

About 50% of candidates were able to give these maximum errors.

Nearly all candidates calculated the maximum % error when weighing using the maximum error they had given for a single balance reading.

The Examiners expected candidates to double the maximum error for a single balance reading when calculating the maximum % error in the masses. Masses are determined by the difference between two balance readings - even if a tare facility is used.

Question 3

- (a) The four cations present, one in each of the solutions provided were given at the beginning of the question. A table for recording observations with each of the specified reagents was provided.

Expected observations for the named ions with the reagents in the table were given in the Qualitative Analysis Notes on the question paper. This part of the question should therefore have been much more straightforward than similar questions in past papers.

Many candidates gave complete and correct observations and were awarded full credit for observations.

As manganese was one of the named ions, lead(II), magnesium and zinc the other three, it was important to accurately describe precipitates as white or off-white in colour.

Despite the descriptions given in the Qualitative Analysis Notes the Examiners saw all too often a white precipitate described as a white solution or a cloudy solution. Candidates should be aware that the appearance of a white colour throughout the solution indicates the formation of a fine white precipitate that is held in suspension.

A number of candidates reported partial solubility of precipitates – a description that does not match any of the ion/reagent combinations in the Qualitative Analysis Notes.

The off-white precipitate, turning brown on standing, was often missed.

The rubric requested candidates to perform test (iii) when no precipitate had been formed in either part of test (i). A considerable number of candidates performed this test with **FB 6** as the initial precipitate had dissolved in excess sodium hydroxide.

Many candidates reported that red litmus paper turned blue for **FB 7** in test (iii) but did not make it clear that it was the gas evolved in this test that was tested with the litmus paper – the solution containing sodium hydroxide would have immediately turned red litmus paper blue.

Some candidates clearly muddled solutions when carrying out their tests.

- (b) As the tests were considered to be very straightforward, no error carried forward from observations was allowed in identifying the ions present. Candidates with correct observations in (a) had no difficulty in correctly identifying the ions present.

Some candidates introduced ions, other than the four given at the beginning of the question, when identifying the ions present.

Error carried forward was allowed in the supporting evidence provided there was no incorrect observation for the ions given. This enabled candidates who had used incorrect **FB** solutions or who had recorded observations under the incorrect **FB** identity to gain partial credit for conclusions.

Many candidates introduced supporting evidence from the Qualitative Analysis Notes, such as the off-white precipitate turning brown on standing for manganese, when there had been no reference to the change in colour of the precipitate in the observations.

- (c) Most candidates correctly recorded no change, no precipitate or no reaction in both of these reactions.
- (d) Most candidates suggested Pb^{2+} as the ion giving similar results to Al^{3+} . Credit was awarded, providing there were no contradictory observations in the reactions in (a) for the solution the candidate identified as containing Al^{3+} ions.
- (e) Most candidates correctly recorded a white precipitate in (i) and a yellow precipitate or the white precipitate turning yellow in (ii). A cream precipitate or any suggestion that the precipitate might be a mixture of a white and a yellow precipitate was not allowed in (ii). The values for the solubility products of silver chloride and silver iodide are so far apart that effectively all of the silver chloride precipitate becomes a precipitate of silver iodide after the addition of aqueous potassium iodide.
- (f) Few candidates were able to give a suitable explanation for the observations above. The Examiners were looking for replacement of the chloride ions (in AgCl) with iodide ions.

Common incorrect or incomplete explanations included the following;

- silver ions react with iodide ions to form silver iodide,
- iodine is responsible for the yellow colour,
- lead iodide is formed,
- chloride displaces iodide,
- there was a redox reaction.



CHEMISTRY

Paper 9701/35

Advanced Practical Skills 1

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data for **Question 1** and **Question 2** for each session/laboratory. Centres are reminded that the Examiners expect to see in the script packet for each Session and for each laboratory within a Session the following documentation;

- a list of the candidates present and a seating plan for the laboratory,
- a copy of the examination paper with the Supervisor's experimental results.

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

Some other Centres do provide Supervisor data for multiple sessions/laboratories but without seating plans or candidate lists and there is insufficient data to place candidates within each session so again candidates may be disadvantaged. Where more than one session/laboratory is used, the candidates should be reminded to complete the boxes on the front page of their scripts with the relevant information.

Comments on Specific Questions

Question 1

The majority of candidates were able to carry out the experimental procedure with a high degree of success and most were able to use the data correctly in the calculation.

- (a) The majority of candidates followed the instructions fully and to the expected level of precision. An increasing proportion of candidates recorded the burette readings for the accurate titres to 0.05 cm^3 . Some candidates would benefit from a reminder as to the appropriate degree of precision with which to report readings taken from standard apparatus. Most candidates performed sufficient accurate titres so that there were two titres within 0.10 cm^3 .
- (b) A large majority of candidates gained credit here. A few made errors by not showing their working, including the rough titre value, or including values that differed by more than 0.20 cm^3 .
- (c) The calculation was well executed by most candidates.

Question 2

This question involved a back titration so the instructions were very detailed and credit could be gained even if the practical section proved problematic.

- (a) The majority of candidates gained credit for the inclusion of (correctly presented) units on pages 5 and 6, and for consistent numbers of decimal places in the three weighings. A few candidates omitted the weighing of the tube + residual **FA 3**, and some reported this to have a lower mass than the tube alone. Candidates should be encouraged to use the same (untared) balance for all their weighings to eliminate systematic errors.
- (b) The majority of candidates gained at least partial credit for the scaled titre. The performance of candidates appeared to be in part Centre dependent and the procedure proved a good test of practical skill.

- (c) No credit was available for this section.
- (d) Most candidates calculated the answer to (i) correctly. Step (ii) caused problems for some as the answer to (i) was not always scaled up x10. Step (iii) was generally well answered and the values from (ii) and (iii) shown in the calculation in step (iv). Candidates should be reminded to use the balanced equations given to find the mole ratios for calculations as the most common mistake in step (v) was to omit dividing the answer to (iv) by 2 or by multiplying instead. Most candidates showed working in the correct direction in at least three of the six steps. However, candidates would benefit from a reminder that all final answers in titration calculations are recorded to 3 or 4 significant figures. Provided they have time, candidates should be encouraged to check through earlier working if they find samples contain more than 100% of the compound.
- (e) Only the more able candidates gained credit here, and the best answers involved the realisation that so little acid would be left unreacted that the titre would be very small hence involve a relatively high error. A common misconception was that the CaCO_3 would be in excess.
- (f) Candidates would benefit from greater exposure to the errors relating to pieces of apparatus and the effect of taking two readings. Some gave the maximum error in measuring the mass of **FA 3** either the same as the error in a single reading or single reading x3. However, the majority of candidates were able to calculate the % error correctly to at least 2 significant figures (using 'error carried forward'). Only the more able candidates were awarded full credit in this section.
- (g) The majority of candidates gave the correct equation with correct state symbols for the thermal decomposition in (i). Few candidates gave sufficiently detailed information about the measurements required in (ii). The most common mistake was to omit weighing a container in which to heat the CaCO_3 , and many did not specify heating and weighing to constant mass.

Question 3

This question was well answered by most candidates apart from the less familiar part (c). Candidates should be encouraged to use the information given in the Qualitative Analysis Notes when describing colours of precipitates and in selecting suitable tests for gases.

- (a) Almost all candidates presented their work in a single table and the vast majority included clear results for using the reagents in excess where necessary even if this was not formally tabulated. The observations for Cr^{3+} or for Zn^{2+} were not always fully correct or were incomplete. Those recording a white ppt with **FA 9** and NH_3 insoluble in excess (incorrect observation) were expected to conclude that two cations, Al^{3+} and Pb^{2+} , may be present.
- (b) The majority selected aqueous barium chloride or nitrate in (i) but a significant minority selected lead nitrate which should have reacted with any halide present. The observations were generally fully correct. Again in (ii) a suitable reagent was selected by most and the observations were usually correct. A few reported a cream ppt with **FA 8**, and some tested **FA 7** unnecessarily as they had already identified it as containing a sulfate. The most common error in this section was to omit the identities of the halides. Candidates should be reminded to write the names or the correct formulae of the reagents; Ba^{2+} is not credited.
- (c) The most commonly awarded credit here was for **FA 10** melting in (i) and reporting a brown gas or blue solution in (ii). An increasing proportion of candidates are including information on the state of the products of reactions. Far fewer candidates appeared to consider appropriate gas tests to carry out on a solid being heated. Candidates should be encouraged to give greater consideration of which gases are likely to be produced on heating or on addition of acid, and be prepared to carry out the requisite tests. The most common test on the gas in (ii) was with litmus paper.

CHEMISTRY

Paper 9701/36
Advanced Practical Skills 2

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data for **Question 1** and **Question 2** for each session/laboratory. Centres are reminded that the Examiners expect to see in the script packet for each Session and for each laboratory within a Session the following documentation;

- a list of the candidates present and a seating plan for the laboratory,
- a copy of the examination paper with the Supervisor's experimental results.

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular session/laboratory and to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

Some other Centres do provide Supervisor data for multiple sessions/laboratories but without seating plans or candidate lists and there is insufficient data to place candidates within each session so again candidates may be disadvantaged. Where more than one session/laboratory is used, the candidates should be reminded to complete the boxes on the front page of their scripts with the relevant information.

Comments on Specific Questions

Question 1

The majority of candidates were able to carry out the experimental procedure with a high degree of success and many were able to use the data correctly in the calculation. Some candidates struggled with the explanation of errors and a modification of the experiment.

- (a) The majority of candidates followed the instructions fully and to the expected level of precision. An increasing proportion of candidates recorded the burette readings for the accurate titres to 0.05 cm^3 . Some candidates would benefit from a reminder as to the appropriate degree of precision with which to report readings taken from standard apparatus. Most candidates performed sufficient accurate titres so that there were two titres within 0.10 cm^3 .
- (b) A large majority of candidates gained credit here. A few made errors with not showing their working, including the rough titre value, or including values that differed by more than 0.20 cm^3 .
- (c) Much of the calculation was well executed by most candidates. Candidates would benefit from a reminder that all final answers in titration calculations are recorded to 3 or 4 significant figures. Step (ii) caused problems for some as the answer to (i) was either not used, the expected $0.125 \times 25/250$ was occasionally inverted, or $0.125 \times 25/1000$ was used.
- (d) Candidates would benefit from greater exposure to the calculation of errors. Only the more able candidates gained at least partial credit in this section. Credit was most often awarded for stating that the errors were in the same direction or that the final reading was also greater than the true value in (i).
- (e) Many candidates knew that the acidic nature of carbon dioxide was the required answer for (i). Fewer were able to suggest a modification of the method, and candidates should be encouraged to discuss possible improvements which may be made to basic techniques when engaged in practical exercises throughout the duration of their course.

Question 2

This question was unfamiliar to all candidates so the instructions were very detailed and credit could be gained even if the practical section proved problematic. The more able candidates usually gained at least partial credit in this question and demonstrated the ability to follow instructions as well as an understanding of equilibrium constants. Weaker candidates gained partial credit for the layout and the practical results even if they were deterred by the unfamiliar requirements.

- (a) The majority of candidate gained credit for the tabulation of results, and at least partial credit for accuracy.
- (b) A substantial number were able to calculate the correct answer of 200 cm^3 in (i). Candidates should be reminded to check units as some gave the answer as '0.2'. Only the more able candidates realised that titre $\times 50/10$ was required in (ii).
- (c) The majority of candidates who answered this part, correctly selected flask B as having most propanoic acid transferred to the organic layer. The justification based on their practical results was not given by all. The most common error was that more organic solvent had been added to flask B.
- (d) Only a minority of candidates attempted this part. Credit was awarded for explaining whether their calculated values for K_c showed equilibrium had been established. The more able candidates gained credit even if the values calculated were numerically incorrect. Some of the best answers incorporated the percentage difference between the two values for K_c in the explanation.

Question 3

This question differentiated well between candidates. The observations were sometimes contradictory between (a) and (b). Candidates should be encouraged to use the information given in the Qualitative Analysis Notes.

- (a) The vast majority of candidates correctly selected aqueous NaOH in (i) as the reagent required to identify the presence of NH_4^+ but many did not give sufficient detail for the test to be awarded credit. Candidates should be reminded that it is a gas that is tested with (damp) red litmus paper. As there was nothing in the instructions to suggest that there was only one cation or one anion in each unknown the supposition that there would be no precipitate with the addition of aqueous NaOH if NH_4^+ was present was unwarranted. Many candidates erroneously reported the presence of NH_4^+ with **FB 8**, and few appeared to warm and test for NH_3 with all three unknowns which was the expected outcome.

The majority selected aqueous barium chloride or nitrate together with hydrochloric or nitric acid in (ii) but a significant minority selected lead nitrate which should have reacted with any halide present. The majority also gained credit for observation though some reported the white precipitate dissolving either in excess $\text{Ba}^{2+}(\text{aq})$ or in the acid used. There are still some candidates stating that sulfuric acid be used in this test. The majority of candidates were able to gain credit for the conclusion in (iii) as it was dependent on their reported results.

- (b) Almost all candidates presented their work in a single table and the majority included clear results for using the reagents in excess where necessary even if this was not formally tabulated. Only a few candidates misinterpreted the rubric and did not test **FB 8** if they believed it to contain NH_4^+ . This section was performed well by the majority of candidates. The most common errors were reporting a grey-green precipitate with **FB 7**, and a white precipitate with **FB 9** and aqueous NH_3 . Candidates should be reminded that a dash is not an observation; words are required to the effect that there is no reaction or no change.
- (c) A large minority of candidates successfully identified Fe^{2+} for **FB 7** and Ca^{2+} for **FB 9** so gained credit here. However, as there was no 'error carried forward' the selection of Cr^{3+} for **FB 7** or Mg^{2+} for **FB 9** meant that credit could not awarded.
- (d) A large majority of candidates gained credit for stating that the solid turned black. Many also gained credit in (ii) for reporting the formation of the green solution. An increasing proportion of candidates are including information on the state of the products of reactions. Far fewer candidates appeared to consider appropriate gas tests to carry out on a solid being heated. The

reporting of effervescence in **(ii)** indicated that insufficient heating was carried out in **(i)**. However, candidates were not penalised and could even gain credit for gas tests if not already awarded in **(i)**. Candidates should be encouraged to give greater consideration of which gases are likely to be produced on heating or on addition of acid, and be prepared to carry out the requisite tests. Many only tested the gas with litmus paper.

CHEMISTRY

Paper 9701/41
A2 Structured Questions

General comments

Almost all candidates were able to make some attempt at every question, and there was no evidence of them running out of time. In fact, many candidates performed better on the later questions in **Section B**.

Once again, electrochemistry topics (**Question 3**) seem to present difficulties and good answers to this question were only seen from the very able candidates. Candidates were not always able to select data from the *Data Booklet* when instructed to do so, and they did not always use the appropriate half equation. It is a common mistake to confuse positive and negative numerical signs in calculations from standard electrode potential values. It would benefit Centres to highlight this area of the syllabus in their teaching.

Many candidates did not read the questions carefully enough. An example of this was in **Question 4(b)** where the instruction to calculate the number of moles of oxygen and lead to 3 significant figures was even printed in bold, yet often ignored. The correct use of significant figures remains a problem and it is important for teachers and candidates to realise that the Examiners expect numerical answers quoted to an accuracy consistent with the data given in the question. Credit cannot be awarded where this is not the case.

The following comments should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

- (a) Few candidates wrote correct, balanced equations here. Many stopped the phosphorus(V) chloride reaction at the POCl_3 stage, and some did not balance either equation.
- (b) Less than a third of candidates were awarded full credit for what should have been a routine calculation. A significant number thought that S_8 was a linear molecule with seven S-S bonds rather than a ring with eight S-S bonds. There was the usual confusion over the sign of ΔH for bond energies.
- (c) In (i) to (iv) the idea of oxidation numbers seemed unfamiliar to a significant number of candidates, and in particular the notion that the oxidation number of an element is zero.
- (v) A significant number of candidates did not notice that they were asked for observations and instead wrote equations. Credit could not be awarded for this.

Question 2

- (a)
- (i) Although many candidates were able to explain what a ligand was, there were still a number of poorly expressed or wrong answers.
- (ii) Four correct answers were rare here, with no more than a third of candidates being awarded full credit.

- (b)
- (i) Several candidates named the compounds here rather than giving their formulae and so could not be awarded credit.
 - (ii) Not everyone recognised that this reaction was an acid-base or neutralisation reaction.
- (c) A large percentage of candidates did not describe what they would observe here. Equations were only correctly balanced in about half the answers from candidates who knew the products.

Question 3

- (a)
- (i) Aside from those candidates who got the electrode reaction mixed up and those who omitted state symbols, this was generally answered well.
 - (ii)(ii) These parts were less well answered with candidates not selecting and quoting appropriate data from the *Data Booklet* or not understanding what the data meant.
 - (iv) Many candidates recognised that this was the reverse equation to (i) and were awarded credit.
 - (v) This was often poorly answered with candidates not using the data to explain the chemistry.
 - (vi) Many candidates assumed that the loss of colour was due to copper being deposited at the cathode, forgetting that it was going into solution at the anode.
- (b)
- (i) The first calculation was generally correctly carried out. Candidates often seemed unsure how to use the current and time to calculate the number of coulombs, and hence moles of electrons used.
 - (ii) Because of the difficulties mentioned in (i), candidates were unsure how to calculate the percentage of the current that was wasted.
- (c) Answers to this part were often poor. Candidates commonly quoted the wrong E^\ominus for iron here and were not sure whether nickel, iron, both or neither would be dissolved or deposited.

Question 4

- (a) Candidates struggled with the relative stabilities of the oxides.
- (b) As already mentioned, candidates often ignored the emboldened instructions to use 3 significant figures here. Even when the calculations were correct, the subsequent conversion to a ratio giving Pb_3O_4 was often incorrect.
- (c) This part was poorly answered starting with the expression for, and units of K_{sp} . Although 'error carried forward' was used, it was unusual for candidates to score more than partial credit.

Question 5

- (a)
- (i) Despite the fact that compound **G** showed the functional group formed in step 5, a large number of candidates did not recognise this as an ester.
 - (ii) Most (but not all) candidates correctly drew **H** as nitrobenzene, but many did not show any charges on **J**, the phenyldiazonium compound.
 - (iii) The various reagents and conditions were often poorly known with a significant number of guesses.

- (b)
- (i) This was often poorly expressed, even by candidates gaining credit on other parts of the question.
 - (ii) Few candidates gave the anticipated functional groups in compound **K**.
 - (iii) Few candidates drew a correct structure for **K** (4-ethanoylphenol).
 - (iv) There were some good answers here, but if candidates could not draw **K**, they often did not know how their structure would react.

Question 6

- (a) Most candidates were able to correctly identify the two chiral centres.
- (b) Some candidates did not appreciate that the dehydration of menthol could use hydrogens from atoms on either side of the one attached to the –OH group. The reagents for the two steps, and the structures of **L** and **M** were only known by the more able candidates.
- (c)
- (i) Only the more able candidates recognised that **N** must have come from a compound where a double bond had been oxidised to give the two carboxylic acid groups.
 - (ii) Even those candidates who recognised the oxidation did not always give a correct structure for the other oxidation product, **P**.
 - (iii) Correct reagents and observations here were generally only given by the most able candidates
- (d) Few candidates scored more than partial credit here, with most showing little idea of how to use 'curly arrows' in a mechanism.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section and the overall performances were probably a little higher than in previous years.

Question 7

- (a)
- (i) Most candidates knew that this was a disulfide linkage.
 - (ii) Again most candidates knew that the reaction affected the tertiary structure.
 - (iii) Although candidates generally knew that the shape of the enzyme would change, a smaller proportion pinned this down to the active site.
- (b)
- (i) Candidates generally recognised this as an acid-base or neutralisation reaction.
 - (ii) Answers to this part were often confused. It would have been better if candidates had written first about the types of interaction – ionic bonds and hydrogen bonds – and then explained why these interactions would be affected.
- (c) It appeared that candidates did not always read the information supplied and tried to answer the questions simply from the structure shown for haem. This often resulted in answers of 'covalent' and 'square planar' in (ii) and (iii), rather than considering bonds which would be at right-angles to the Fe – N plane giving an octahedral structure using co-ordinate bonding.

Question 8

- (a) A pleasing number of candidates were able to identify the two sub-atomic particles, although unfortunately some referred to protons as 'hydrogen atoms'. The explanations as to how each method worked were less detailed than needed or absent altogether.
- (b)
- (i) Candidates are expected to appreciate that removing hydrogen atoms (by oxidation) would reduce the number of peaks in the NMR spectrum and hence state that spectrum 1 was produced by the alcohol.
 - (ii) Some candidates either did not know how to use the M:M+1 data, or chose to ignore it. This calculation indicated that Y contained three carbon atoms. Since spectrum 2 contains hydrogen atoms in only one environment (1 peak), this pointed to propanone as compound Z, and hence propan-2-ol as compound Y.
 - (iii) A good percentage of candidates were awarded credit here.
 - (iv) Lots of candidates pointed out that one peak indicates protons in only one chemical environment.

Question 9

- (a)
- (i) Although many candidates could give the approximate width, a large number did not give any units.
 - (ii) Few candidates gave graphite (or graphene) here with 'buckyballs' being a common incorrect answer.
 - (iii) Candidates should be able to recognise carbon and hydrogen as elements with similar electronegativities and hence suggest van der Waals' forces here.
- (b) Lots of candidates were able to use their chemistry and common sense to suggest that more fuel could be stored in the same amount of space this way.
- (c) Few candidates could give an accurate definition of Le Chatelier's principle, which then made it hard for them to use it in explaining the pressure changes in the fuel tank. Lots also referred to the 'forward reaction' or the 'backward reaction' without writing an equilibrium to show what these terms meant.

CHEMISTRY

Paper 9701/42
A2 Structured Questions

General comments

Almost all candidates were able to make some attempt at every question, and there was no evidence of them running out of time. In fact, many candidates performed better on the later questions in **Section B**.

Once again, electrochemistry topics (**Question 3**) seem to present difficulties and good answers to this question were only seen from the very able candidates. Candidates were not always able to select data from the *Data Booklet* when instructed to do so, and they did not always use the appropriate half equation. It is a common mistake to confuse positive and negative numerical signs in calculations from standard electrode potential values. It would benefit Centres to highlight this area of the syllabus in their teaching.

Many candidates did not read the questions carefully enough. An example of this was in **Question 4(b)** where the instruction to calculate the number of moles of oxygen and lead to 3 significant figures was even printed in bold, yet often ignored. The correct use of significant figures remains a problem and it is important for teachers and candidates to realise that the Examiners expect numerical answers quoted to an accuracy consistent with the data given in the question. Credit cannot be awarded where this is not the case.

The following comments should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

- (a) Few candidates wrote correct, balanced equations here. Many stopped the phosphorus(V) chloride reaction at the POCl_3 stage, and some did not balance either equation.
- (b) Less than a third of candidates were awarded full credit for what should have been a routine calculation. A significant number thought that S_8 was a linear molecule with seven S-S bonds rather than a ring with eight S-S bonds. There was the usual confusion over the sign of ΔH for bond energies.
- (c) In (i) to (iv) the idea of oxidation numbers seemed unfamiliar to a significant number of candidates, and in particular the notion that the oxidation number of an element is zero.
- (v) A significant number of candidates did not notice that they were asked for observations and instead wrote equations. Credit could not be awarded for this.

Question 2

- (a)
- (i) Although many candidates were able to explain what a ligand was, there were still a number of poorly expressed or wrong answers.
- (ii) Four correct answers were rare here, with no more than a third of candidates being awarded full credit.

- (b)
- (i) Several candidates named the compounds here rather than giving their formulae and so could not be awarded credit.
 - (ii) Not everyone recognised that this reaction was an acid-base or neutralisation reaction.
- (c) A large percentage of candidates did not describe what they would observe here. Equations were only correctly balanced in about half the answers from candidates who knew the products.

Question 3

- (a)
- (i) Aside from those candidates who got the electrode reaction mixed up and those who omitted state symbols, this was generally answered well.
 - (ii)(ii) These parts were less well answered with candidates not selecting and quoting appropriate data from the *Data Booklet* or not understanding what the data meant.
 - (iv) Many candidates recognised that this was the reverse equation to (i) and were awarded credit.
 - (v) This was often poorly answered with candidates not using the data to explain the chemistry.
 - (vi) Many candidates assumed that the loss of colour was due to copper being deposited at the cathode, forgetting that it was going into solution at the anode.
- (b)
- (i) The first calculation was generally correctly carried out. Candidates often seemed unsure how to use the current and time to calculate the number of coulombs, and hence moles of electrons used.
 - (ii) Because of the difficulties mentioned in (i), candidates were unsure how to calculate the percentage of the current that was wasted.
- (c) Answers to this part were often poor. Candidates commonly quoted the wrong E^\ominus for iron here and were not sure whether nickel, iron, both or neither would be dissolved or deposited.

Question 4

- (a) Candidates struggled with the relative stabilities of the oxides.
- (b) As already mentioned, candidates often ignored the emboldened instructions to use 3 significant figures here. Even when the calculations were correct, the subsequent conversion to a ratio giving Pb_3O_4 was often incorrect.
- (c) This part was poorly answered starting with the expression for, and units of K_{sp} . Although 'error carried forward' was used, it was unusual for candidates to score more than partial credit.

Question 5

- (a)
- (i) Despite the fact that compound **G** showed the functional group formed in step 5, a large number of candidates did not recognise this as an ester.
 - (ii) Most (but not all) candidates correctly drew **H** as nitrobenzene, but many did not show any charges on **J**, the phenyldiazonium compound.
 - (iii) The various reagents and conditions were often poorly known with a significant number of guesses.

- (b)
- (i) This was often poorly expressed, even by candidates gaining credit on other parts of the question.
 - (ii) Few candidates gave the anticipated functional groups in compound **K**.
 - (iii) Few candidates drew a correct structure for **K** (4-ethanoylphenol).
 - (iv) There were some good answers here, but if candidates could not draw **K**, they often did not know how their structure would react.

Question 6

- (a) Most candidates were able to correctly identify the two chiral centres.
- (b) Some candidates did not appreciate that the dehydration of menthol could use hydrogens from atoms on either side of the one attached to the –OH group. The reagents for the two steps, and the structures of **L** and **M** were only known by the more able candidates.
- (c)
- (i) Only the more able candidates recognised that **N** must have come from a compound where a double bond had been oxidised to give the two carboxylic acid groups.
 - (ii) Even those candidates who recognised the oxidation did not always give a correct structure for the other oxidation product, **P**.
 - (iii) Correct reagents and observations here were generally only given by the most able candidates
- (d) Few candidates scored more than partial credit here, with most showing little idea of how to use 'curly arrows' in a mechanism.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section and the overall performances were probably a little higher than in previous years.

Question 7

- (a)
- (i) Most candidates knew that this was a disulfide linkage.
 - (ii) Again most candidates knew that the reaction affected the tertiary structure.
 - (iii) Although candidates generally knew that the shape of the enzyme would change, a smaller proportion pinned this down to the active site.
- (b)
- (i) Candidates generally recognised this as an acid-base or neutralisation reaction.
 - (ii) Answers to this part were often confused. It would have been better if candidates had written first about the types of interaction – ionic bonds and hydrogen bonds – and then explained why these interactions would be affected.
- (c) It appeared that candidates did not always read the information supplied and tried to answer the questions simply from the structure shown for haem. This often resulted in answers of 'covalent' and 'square planar' in (ii) and (iii), rather than considering bonds which would be at right-angles to the Fe – N plane giving an octahedral structure using co-ordinate bonding.

Question 8

- (a) A pleasing number of candidates were able to identify the two sub-atomic particles, although unfortunately some referred to protons as 'hydrogen atoms'. The explanations as to how each method worked were less detailed than needed or absent altogether.
- (b)
- (i) Candidates are expected to appreciate that removing hydrogen atoms (by oxidation) would reduce the number of peaks in the NMR spectrum and hence state that spectrum 1 was produced by the alcohol.
 - (ii) Some candidates either did not know how to use the M:M+1 data, or chose to ignore it. This calculation indicated that Y contained three carbon atoms. Since spectrum 2 contains hydrogen atoms in only one environment (1 peak), this pointed to propanone as compound Z, and hence propan-2-ol as compound Y.
 - (iii) A good percentage of candidates were awarded credit here.
 - (iv) Lots of candidates pointed out that one peak indicates protons in only one chemical environment.

Question 9

- (a)
- (i) Although many candidates could give the approximate width, a large number did not give any units.
 - (ii) Few candidates gave graphite (or graphene) here with 'buckyballs' being a common incorrect answer.
 - (iii) Candidates should be able to recognise carbon and hydrogen as elements with similar electronegativities and hence suggest van der Waals' forces here.
- (b) Lots of candidates were able to use their chemistry and common sense to suggest that more fuel could be stored in the same amount of space this way.
- (c) Few candidates could give an accurate definition of Le Chatelier's principle, which then made it hard for them to use it in explaining the pressure changes in the fuel tank. Lots also referred to the 'forward reaction' or the 'backward reaction' without writing an equilibrium to show what these terms meant.

CHEMISTRY

Paper 9701/43

A2 Structured Questions

General comments

Almost all candidates were able to make some attempt at every question, and there was no evidence of them running out of time. In fact, many candidates performed better on the later questions in **Section B**.

Electrochemistry topics (**Question 5**) seem to present difficulties and good answers to this question were only seen from the very able candidates. Candidates could select data from the *Data Booklet* when instructed to do so; although in **Question 5(a)(i)** they did not always use the appropriate half equation. It is a common mistake to confuse positive and negative numerical signs in calculations from standard electrode potential values and also in enthalpy change calculations – as in **Question 1(b)(v)**.

The Examiners once again noted that many of candidates did not read the question carefully. As an example, in **Question 5(c)(ii)** the majority of candidates did not note the instruction *Hence explain*, indicating that the answer should be based on the previous answers in **(i)**, and instead they attempted to refer to changes in equilibrium position.

The following comments should be read in conjunction with the published mark scheme for this paper.

Comments on specific questions

Section A

Question 1

(a)

- (i) Most candidates knew that the product of the reaction would be an acid but a variety of incorrect options were offered in place of the correct answer, H_3PO_4 . In the second equation, H_2SO_4 was often seen instead of H_2SO_3 .
- (ii) Many candidates correctly identified the two acids, HNO_2 and HNO_3 , but a number left the equation unbalanced.
- (iii) This part proved more demanding and answers suggested either a lack of understanding of oxidation numbers, or more probably no appreciation that the oxidation numbers of chlorine in the proposed salts should differ from that in ClO_2 by +1 and –1.

(b)

- (i) Whilst the missing formulae of O_2 , CO_2 and H_2O were usually given, a significant number of candidates did not correctly balance the equation.
- (ii) Candidates who did not gain credit here usually had not appreciated that it was the product of H_2S combustion (SO_2) that was the cause of acid rain and subsequent harmful effects, rather than H_2S itself.
- (iii) This calculation was successfully tackled by many candidates, although not fully taking account of the question's reference to *room temperature*, meant that some candidates used a molar gas volume of 22.4 rather than 24 dm^3 .
- (iv) Very few candidates recognised this as an acid-base reaction. Most commonly it was incorrectly proposed to be a redox reaction.

- (v) Whilst there were many candidates who not only gave the correct answer to this calculation but also showed the logic of their working clearly, there were some who confused signs to give a positive value for ΔH . Some candidates did not read the question correctly and performed complicated and confused calculations involving both equations given in the question.

Question 2

- (a) There were some very concise and precise answers to this question, given by some able candidates, containing the three key points – splitting of d-orbital energies / electron promotion with absorption of energy / relationship of energy to visible light and consequent colour. Weaker candidates who had some knowledge of the answer often wrote at length but seldom covered more than the third point.
- (b) The majority of candidates could correctly relate the blue colour to the $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ion and could recognise that ligand replacement occurred, but far fewer gave a correct formula for the $[\text{CuCl}_4]^{2-}$ ion. Many of these suggested that it was an ammine complex.
- (c) Although not all candidates attempting the calculation recognised the 1:1 relationship of $\text{Cu}^{2+} : \text{S}_2\text{O}_3^{2-}$, many correctly calculated $[\text{Cu}^{2+}]$. The final step to find the percentage of copper proved to be more difficult. Common errors were to overlook the dilution factor or to use an incorrect molar mass.

Question 3

- (a) Many candidates recognised that oxidation and reduction (or hydrogenation) were involved here, although the terms were not always assigned the right way round.
- (b) This question was seldom well answered. Correct identification tests were more frequently given for thymol than for the other two compounds. Errors included the use of acidified KMnO_4 for menthol and reducing agents, such as Fehling's solution, for menthone. Credit could not be awarded for imprecise identifications of reagents; iron(III) chloride solution is required for thymol, for example, or for inadequate descriptions of observations; 2,4-DNPH gives an orange precipitate or solid, not just colour.

Question 4

Candidates often performed well on this question. The azo compound **X** was not always well drawn and was shown with N-N-O bonds or single or triple NN bonds. The rest of the question was frequently well answered although essential conditions were sometimes omitted. Heat was expected in reactions **III** and **V** and maximum temperature conditions are necessary for reactions **IV** and **VII**. The presence of aqueous conditions would not enable the first two halogenation reactions to proceed.

Question 5

In general this question was poorly answered throughout, apart from (d), suggesting that it is a topic that candidates find confusing. There was some indication that they had also not read and fully understood the question.

- (a) Many candidates failed to note the reference to *neutral conditions* and gave equations for reactions that involved OH^- ions.
- (b) Whilst credit was given for correct calculation from incorrect data due to errors in (a), there was a number of candidates who confused numerical signs in their addition or subtractions of electrode potentials. Some candidates did not know how to obtain E^\ominus_{cell} from the half cell potentials.
- (c) Despite being given three phrases from which to select their answer to (i), some candidates gave their own responses such as 'less negative'. Unfortunately the majority did not read or appreciate the instruction in (ii). As indicated in the general comments, it was expected that candidates would use their answers of 'no change' and 'less positive' in (i) to explain that the production of O_2 would stay the same, whilst that of Cl_2 would decline. This would give a decrease in the stated ratio of

the gases. The word *Hence* was commonly overlooked or ignored and candidates wrote explanations involving changes in equilibrium.

- (d) Candidates who persevered with the question as far as (d) usually gained credit for the calculation, although not always full credit as some overlooked the requirement for 6 Faradays per mole of NaClO_3 .

Question 6

- (a)
- (i) Some candidates could not be awarded credit for stating bromine as a reagent as they gave light as a required condition.
 - (ii) Description of the mechanism was often poorly done. A significant number of candidates did not follow the convention of arrows representing movement of pairs of electrons but used them to show bromine (molecules or atoms) as attacking species towards the double bond. Others simply lacked care in locating the start and finish points of the arrows, suggesting electron pair donation from a carbon atom. Partial charges, rather than a full + or -, were often incorrectly shown on the cation intermediate and the bromine anion.
- (b) This was usually well answered but some candidates seemed confused by the use of skeletal formulae and misinterpreted the number of carbon atoms in the chain.
- (c) The use of an oxidising agent in reaction II rather than acid hydrolysis was a common mistake.
- (d) Rather surprisingly correct answers of NH_4^+ were very rarely seen. Many answers given did not even contain nitrogen.
- (e) Incorrect answers usually either did not show *one repeat unit* or were dimers with terminal atoms included rather than continuing bonds.
- (f) The first part of the calculation was often completed correctly; the second part less frequently.

Question 7

- (a) Despite the instruction to *write equations for two reactions* a single overall equation was often given. Other errors included unbalanced equations in which atoms or ions were 'lost' or that did not show the products as ionic.
- (b) Graphs were poorly drawn in terms of both shape and start and finish pH values. Even in a sketch graph the Examiners expected these points to lie close to the values of 11.3 and 1.6 rather than 12 and 0. Only a very small minority of candidates recognised that there would be two inflections on the graph, at 10 and 20 cm^3 .

Question 8

- (a) Although most candidates thought that the SiCl_4 molecule was tetrahedral, this was not always clearly apparent from their diagrams that seemed to show a square-planar form. Many candidates did not give the explanation for the shape, which required reference to the number of electron bond pairs and the absence of lone pairs. Having drawn correct molecules, some candidates described ionic, metallic or covalent macromolecular bonding.
- (b) Most candidates wrote a satisfactory equation showing the formation of HCl , although they did not always describe the observation of steamy fumes that would be apparent.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section and the overall performances were probably a little higher than in previous years.

Question 9

This question was well answered by a large number of candidates and it was not unusual to award full credit.

- (a) Some candidates incorrectly gave ribose as a constituent compound.
- (b) Many candidates showed some knowledge of the backbone structure to DNA. Inadequately labelled diagrams, lacking a correct base pairing or with an incorrectly linked sequence of the constituent molecules, were common errors.
- (c) Almost all candidates correctly started the sequence with mRNA but not all completed it in the right order.
- (d) The majority of candidates were awarded full credit. The only common error was not to include Met or Start at the beginning of the sequence.

Question 10

- (a)
 - (i) Although most candidates attempted this, answers were often too vague or confused to gain credit. Few candidates appeared to understand the significance of relative solubilities in partition chromatography and attraction of the solute to a solid surface in adsorption chromatography. Many, for example, referred to adsorption of the solvent on a solid.
 - (ii) Linked with the misunderstandings in (i), the majority of candidates incorrectly identified paper chromatography as adsorption separation rather than partition between the mobile solvent phase and stationary water bonded to the paper. The other two methods were usually described correctly.
 - (iii) Relatively few candidates appreciated that the relative percentages were indicated by the heights of the peaks (as the bases were of equal width) and that they needed to measure and compare these.
- (b) This part of the question was much better answered with many candidates being awarded full credit. Some answers were too imprecise to gain credit in (i) and mentioned carbon and hydrogen in organic compounds without referring to the significance of the different chemical environments of the hydrogen atoms or protons. Only a small minority of candidates did not draw correct structures for propanal and propanone and then go on to predict the number of peaks for each. A few candidates confused NMR with mass spectroscopy.

Question 11

- (a) Thoughtful candidates were easily able to suggest two sensible reasons why injection of drugs was advantageous in comparison to oral application. Unfortunately significant numbers did not read the question properly and gave avoidance of digestive breakdown as an answer.
- (b) This part of the question was less often attempted and where it was, circles sometimes embraced far larger sections of the molecule than the functional group. The Examiners accepted either correctly circled bonds that would be broken or whole ester or amide functional groups, but not when circles contained carbon atoms on the rings or the extended chains. The two circled groups could be both esters or an ester and an amide.
- (c)
 - (i) Possibly because they did not think about and assimilate the information contained in the stem to this question, very few candidates were able to offer suitable suggestions for this answer. Most attempts referred to water or acidic conditions rather than other properties.
 - (ii) Most candidates did refer to the effect of the acidic conditions in the stomach although some indicated that saliva or the mouth were acidic.

- (d) Whilst usually correctly attempted, full credit could have been awarded more often if candidates' equations for addition and condensation polymerisations included a multiplier of n moles of monomer and were balanced.
- (e) Most candidates correctly identified this as a hydrolysis reaction.

CHEMISTRY

Paper 9701/51

Planning, Analysis and Evaluation

General comments

Overall, the paper once again proved to be quite challenging with some of the part questions only occasionally producing a correct response. Nevertheless, correct responses to all the questions were seen with some candidates producing some excellent answers. Some candidates found the precision of answer required by some of the questions quite demanding. An enhanced familiarity with experimental techniques would be of benefit to all candidates.

Comments on Specific Questions

Question 1

- (a) Most candidates received credit for a statement that there would be an increase in the number of moles of lead chloride. Less frequently correct was the explanation for this increase. The essence of the correct answer was to refer directly or indirectly to the given equation. Some candidates, correctly appreciating that the limited supply of lead nitrate would eventually lead to a maximum mass of lead chloride, were awarded full credit by describing the shape of the graph expected in (b).
- (b) The possible limiting factors needing to be taken into account are the number of moles of lead nitrate and the concentration or the total volume of the lead nitrate. Only the more able candidates were successful here. The required graph was made up of two linear parts with a sharp change of direction corresponding to the point at which the maximum mass of lead chloride was reached. Again the able candidates achieved this. More common was a curved shape levelling off at some point; such a response was awarded partial credit.
- (c) Only a small number of candidates were able to provide the three correct responses. The most frequent error was in not identifying temperature as the variable to be controlled.
- (d) Often there was no recorded detail as to how to prepare a standard solution of lead nitrate. Those that did attempt this generally only achieved partial credit for the correct mass of lead nitrate needed to make up 250 cm³ of solution. Perhaps the candidates were unfamiliar with the procedure for preparing a standard solution. There was a tendency to prepare the solution in a beaker or to add the mass of solid directly to a volumetric flask already filled to the mark with deionised water. Both of these methods are incorrect.

A small number of candidates began the preparation of the solution from another given solution of lead nitrate, while others began with lead and nitric acid.

The detailed volumes of the two reagents were correctly given by most candidates as was the measurement method. The correct drying of a precipitate should only involve the minimum of heating, such as washing with propanone or the controlled use of a desiccator whereas the popular version involved heating with a Bunsen burner. Such heating of course could lead to decomposition of the solid.

- (e) On many occasions full credit was awarded for completing the table, but common errors included omission of the 'mole' columns and errors in the stated volumes. The latter was either complete omission of volumes or total volumes which exceeded 250 cm^3 .
- (f) Many of the responses here were clear and correct with a small number offering the suggestion that repeating the weighing without any further heating would suffice.

Question 2

This question was about the variation of the freezing point of a solution with concentration, a concept possibly unfamiliar to most candidates. Measurements of freezing points traditionally use the concept of molality. This would certainly be unfamiliar to candidates and hence the concept and definition was given in the paper.

- (a) In nearly all cases the value of the molar mass of glucose was correctly calculated.
- (b) Most candidates attempted to produce two columns, one showing the number of moles of glucose the other the molality, although some candidates produced the molality column alone, which also gained credit.

Candidates struggled with giving correct column headings. While the first column heading, if given was often correct (B/180) it was in the molality column that most difficulty was experienced. The most frequent of the possible errors was giving a flawed expression for the calculation although units were omitted and there was the inevitable slip back to molarity. In almost all cases, the column(s) were completed with results using the stated expression. However, there appears to be continuing confusion between significant figures and decimal places with many candidates not producing the required results.

- (c) In the graph plotting most candidates correctly assigned the molality to the x-axis as the independent variable. Some candidates did create plotting problems for themselves while at the same time making accuracy checking difficult by choosing scales which resulted in each small square being equivalent to difficult decimal amounts such as 0.033 units. While it is appropriate to utilise the maximum amount of the graph paper this should not be to the detriment of accurate scale readings. Nevertheless, the plotting was generally good and the straight lines were well drawn. The two main difficulties with the drawing of the line were lines seemingly made up of two halves (possibly as a result of using a short rule) and a line not passing through the origin.
- (d) With accurate plotting and a correctly drawn line there were two clearly anomalous points, one on each side of the line. However, credit for identifying the anomalous points was based on the candidate's correct plotting and line drawing and this on occasions led correctly to either one or more than two anomalous points. The correct interpretation of how the anomalies arose was difficult and many candidates found this too challenging. The correct interpretations needed to be based on explaining why the solution was either too concentrated or too dilute. Acceptable alternatives were suggestions of premature or late thermometer readings.
- (e)
- (i) The lines on the graph were usually well drawn with correct intercepts read. However, most calculations although numerically correct lacked any units. Where units were given these were usually correct.
 - (ii) The linear nature of the results was an appropriate comment here as was the comment that most of the points lay close to a straight-line. The comment by some candidates that the line passed through the origin was of no value as a lone statement.
- (f) An appreciation that the depression of freezing point depends on the number of particles in solution, as detailed at the beginning of the question, should have led the candidates to the conclusion that since sodium chloride is in the form of two ions in solution the freezing point depression would be doubled.
- (g) A correct answer was seen only occasionally. A quite popular incorrect explanation involved a comparison of the molar masses of glucose and sodium chloride.

- (g) Similar reasoning to that in (f) should lead to a freezing point depression intermediate between that of glucose and sodium chloride. Again, correct answers were infrequent.

CHEMISTRY

Paper 9701/52

Planning, Analysis and Evaluation

General comments

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- (f) An appreciation that the depression of freezing point depends on the number of particles in solution, as detailed at the beginning of the question, should have led the candidates to the conclusion that since sodium chloride is in the form of two ions in solution the freezing point depression would be doubled.
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- (g) Similar reasoning to that in (f) should lead to a freezing point depression intermediate between that of glucose and sodium chloride. Again, correct answers were infrequent.

CHEMISTRY

Paper 9701/53

Planning, Analysis and Evaluation

General comments

In general this examination followed the usual format.

In **Question 1** the table of results was usually very well done. Candidates would probably benefit from more experience of setting up an apparatus where reagents need to be kept separate.

In **Question 2** the required calculations in the table were found quite difficult by some candidates.

Two points about data tables are common every session. Firstly, candidates need to label each new column used. These labels require three items – a written label, a correct unit and an expression to be used to calculate the column data. All of these items are required for credit to be awarded (often the expression is omitted). Secondly, the data needs to be correctly quoted, to either a specified number of decimal places or significant figures. In this examination, the data requirement was for 3 significant figures. Usually, the table head and data requirements are given below the table, so candidates should be advised to look there before calculating any data.

In scaling the axes on a graph plot, candidates should always consider if the true origin (0,0) would be a point on the line. If so, it should always be included in the scales since it would always be a reliable, correct point. Two factors need to be taken into account when scaling the axes. The points need to be plotted within at least half of each axis and the scale should be reasonable to facilitate accurate plotting. For example data of 1, 2, 4 or 5 to 1 large square (of 10 small squares) would be reasonable but 3 or 6 or 7 to 1 large square (of 10 small squares) would not. Some candidates would benefit from practice in fitting a reasonable scale into the grid first that uses at least half of each axis.

When referring to the reason for an anomalous result, it should be stressed to candidates that they unambiguously define the point (e.g. Experiment 4) before stating a reason. This is vital when there is more than one anomaly.

Comments on Specific Questions

Question 1

(a)

(i) Most candidates correctly related an increase in concentration to produce an increase in the rate of reaction. Responses to the explanation were less successful often relying on “more” collisions which does not directly equate to a higher collision frequency. Many had the notion that this reaction was being enzyme catalysed or that this was a reversible reaction in equilibrium. A few candidates referred to the limiting saturation of the catalyst surface.

(ii) Sketch graphs were usually good. A few good lines did not start at the origin which was unfortunate.

(b)

The two variables were often named well. Care is needed in the independent variable where volume/moles/amount is often used where only concentration is acceptable. The use of “amount” is generally best avoided. The rate of reaction is a derived quantity from time to a set volume thus the time is the dependent variable. Multiple answers to a single question which carries a single marking point are open to error where such a list can contain an incorrect response that negates a correct one. Thus list responses are also best avoided.

- (c) Most candidates attempted a diagram and most were awarded partial credit. Virtually no candidates had a way of keeping the two reactants apart, but both within the closed reaction vessel. It seems that this sort of practical technique was not well known. The use of a dropping funnel (or even a thistle funnel) to add a liquid reagent does keep the reagents separate but would not work in this situation due to the displaced air (when the liquid is added) upsetting the rate of oxygen (gas) production. The capacity of the gas collector was usually, but not always, given. Too many candidates included an unnecessary burner.
- (d)
- (i) Quite a lot of information was required here. Many were successful in completing the 3 columns. The tables of data required units (as asked for in the question). CIE require that units in table headings are as mol dm^{-3} or cm^3 . A few candidates had a 0 cm^3 value for hydrogen peroxide which would not produce a hydrogen peroxide solution – possibly candidates erroneously thought a “control” was necessary. Most calculated a correct concentration for each mixture but a minority mis-understood and wrote 2 mol dm^{-3} for all. Some thought equal volumes of hydrogen peroxide and water (five different) gave different concentrations, but they would all be 1 mol dm^{-3} .
- (ii) The description was moderately well done with most gaining partial credit. A common omission was using hydrogen peroxide solution without the catalyst being present. The experimental requirements need clearly stating, e.g. the reaction vessel needing closing as soon as the reactants are mixed and that the stop clock needs starting immediately as the reactants get together. There were many statements of just “start the clock” sufficiently divorced from the reaction start to be taken as some time after the reaction start. It was apparent from the success in (e) that the immediacy may have been understood, but was not properly described. Most correctly described stopping the clock at a set volume but a significant minority described the end of reaction or cessation of gas production instead of referring to a fixed volume as required by (b).
- (e) Most candidates realised that multiple operations were involved with the start of the reaction and starting the clock. Some who had a burner may have thought that lighting the burner was starting the reaction.
- (f) The table was done quite well - much better than in previous years - and the majority of candidates gained full credit. On occasion, one of the required columns was missing. The units were often well reported.

Question 2

- (a) Candidates should be encouraged to read the text below the table before completing the table.

There are two common errors in these tables that occur regularly.

Each column heading needs three things, a description (e.g. concentration of acid in water), a unit (e.g. mol dm^{-3}) and an expression to calculate the data (e.g. $B \times 0.1/20$) as required in the text below the table.

Also below the table is stated a requirement for a specific number of significant figures or decimal places. There is a general misunderstanding of the difference between significant figures, decimal places and trailing zeros. In this case the requirement was for three significant figures. There was a frequent misunderstanding of this requirement. For example, 0.0105 (3sig figs.) was given as 0.011 (3dp), even to the extent of seeing 0.0105 written but crossed out and replaced by 0.011 where, presumably, the candidate believes three decimal places is the same as three significant figures. Also a calculated value of 0.05 needs to be reported as 0.0500 if three significant figures are required. Care needs to be taken with the reporting of data.

The two required columns involved a great deal of calculation. Each column required the calculation of moles of sodium hydroxide, converting this into moles of succinic acid then a concentration of acid. Only the more able candidates had any success here. Many managed two parts of these calculations but usually not the 2:1 relationship between succinic acid and sodium hydroxide. This may have been due to unfamiliarity with succinic acid or its formula. Quite a significant minority labelled the columns “moles of sodium hydroxide” rather than concentration in each solvent even though this was stated below the table.

- (b) The scaling of the axes seems to cause misjudgement in the minds of some candidates. There seems to be a determination to cover the whole span of the grid regardless of the implications of the axis scaling necessary to achieve that. An example of difficult scaling is 1 large square being 0.03. This would make each small square (1 mm) 0.003. This creates difficulties for the candidate in correctly plotting data of the nature of 0.00552 so mis-plotting is often seen when such inconvenient scales are chosen. Another example of difficult scaling was a 1 mm square being 0.00218 on the x -axis and 0.000223 on the y -axis. Such scales require the extensive use of a calculator to adequately plot the data which in the very least may take some time. Some candidates chose a scale for the acid concentration in water that did not accommodate all the points giving the last point outside the grid. The scaling chosen must adequately cover the available grid but the minimum requirement is for the plot to cover at least half of the grid in both directions. So the candidates must make a compromise between scaling and grid coverage to use at least half of the grid in both directions with a reasonable scale that can be easily used. Much better scaling for the concentration in the water layer would have been 1 large square for 0.0125 or 0.02 mol dm⁻³ (depending on which axis) and for the concentration in the ether layer, 1 large square for 0.001 mol dm⁻³.

Two more factors need to be considered in graph work. Firstly it is the independent variable that is to be plotted on the x -axis and the dependent on the y -axis. Almost uniquely in this particular question either variable could be plotted on either axis. Secondly the data/relationships should always be examined to see if the origin (0,0) is a valid point. If so (as in this question) then the scaling used must include the origin and any line drawn would include the origin since it would be a definite point not subject to any experimental error as the other points may be.

The axes were mostly unambiguously labelled. The plotting (given reasonable scales) was usually well done as were most of the straight lines. Some lines were two separate lines joined together (with a slight bend) and the straight lines needed to be drawn into the origin.

- (c) Most candidates who had some reasonable data (not necessarily correct) in the table could identify two anomalies, one on each side of the line. Some candidates who had over rounded data giving multiple 0.01/0.02 values in the table inevitably had 5 or 6 anomalies which in a data table of 10 experiments is extremely unlikely.

The descriptions of causes for anomalies needed to be more logically done. Before describing the error, the anomalous point had to be unambiguously identified e.g. experiment 4 or a label written on the graph. Then the nature of the anomaly e.g. concentration in the ether layer is too low, then finally the cause e.g. the titration was terminated before the end point. Thus a quite specific answer is required. Thus "Point 8 is anomalous as the concentration of acid in the ether layer is too high because the titration was overshot past the end point" would gain credit. Commonly found were answers such as "Concentration was low because the titration was wrong" which were not related to a point or to which of the two solvents involved nor as to why the titration was wrong. These lack any specificity and cannot gain any credit. Unfortunately, most answers were unrelated to a particular point and solvent and were also too vague in the error.

- (d)
- (i) A requirement for determining a slope is the use of construction lines on the plot to produce co-ordinates for the slope calculation. Many candidates did not draw construction lines. The co-ordinates of a table point may be used provided they lie on the line and the construction lines are drawn to them. If plotted the origin is a good point to use. If not, it cannot be assumed. Given suitable data, most candidates correctly calculated a value for the slope. Some candidates presented their data in standard form e.g. 2.76×10^{-3} rather than 0.00276 and plotted the values in standard form. Unfortunately some candidates then transferred 2.76 into their calculation rather than 2.76×10^{-3} .
 - (ii) More candidates would have gained credit here if they had stated "straight line" instead of "line". Direct proportionality as is the case with partition coefficient is defined only by a straight line. The answer of "line" is an insufficient definition as it would include any sort of line.
- (e) Only the more able candidates realised that the added water is to extract the succinic acid into an aqueous phase so that it can react with the sodium hydroxide and thus be titrated. Some answers

restated the question as “It needs to be shaken to work” or suggested that ether reacted with the sodium hydroxide.

- (f) Most candidates did well on this final question. It was pleasing to see that it was understood that low titre values have the most percentage error and that this was correctly reported as a high percentage error rather than just high error. It appeared known that the burette error of $\pm 0.1 \text{ cm}^3$ that applies to all titres is a very different thing from the percentage error in each different titre. Candidates should be advised that when discussing relative errors only percentage errors should be used.