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CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to the candidates with some pleasing performances.

Thirteen questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 1, 4, 10, 11, 12, 14, 18, 19, 23, 27, 28, 33**, and **36**. Eight questions can be said to have been found to be particularly difficult. Less than 25% of candidates chose the correct responses to each of **Questions 2, 5, 9, 13, 21, 22, 29** and **40**.

Comments on Specific Questions

Question 2.

24% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 32% of candidates. In **A** the oxidation state of N changes from -3 to +2, so this is the greatest change.

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Question 5.

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**, chosen by 32% of candidates. It can therefore be assumed that most candidates knew that initially the rate would increase, as catalyst was produced. However the correct answer is **C** as eventually reactants will get used up and the rate will decrease.

Question 9.

29% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 32% of candidates. Those who chose **D** did not appreciate that a change in the number of moles of N_2 must be accompanied by a change in the number of moles of H_2 and NH_3.

Question 13.

24% of candidates chose the correct answer, **A**. The other three answers were chosen in approximately equal amounts, suggesting that many candidates may have guessed. Of the four metals given, only barium will react with water <u>and</u> has an insoluble sulfate.

Question 21.

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 37% of candidates. **D** is incorrect as propene will have very little reaction with aqueous HC*l*. The reaction described in **C** will give 1-chloropropane in good yield.

Question 22.

27% of candidates chose the correct answer, **C**. The other three answers were chosen in approximately equal amounts, suggesting that many candidates may have guessed. Although the question looks very complicated it actually rests on one fact; a C=C double bond is not oxidised by $H^+/Cr_2O_7^{2-}$. Candidates who chose **A**, **B** or **D** were probably confusing the use of $H^+/Cr_2O_7^{2-}$ with the use of H^+/MnO_4^- under varying conditions.

Question 29.

17% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 46% of candidates. It could be that candidates who thought the answer was **B** realised that the two carboxylic acids would give salts, but did not realise that the two esters would be hydrolysed, also giving salts.

Question 40.

22% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 44% of candidates. Statement 1 is correct as butanal reacts with HCN to give $C_2H_5CH(OH)CN$, which is chiral. Statement 2 is incorrect as pentan-3-one reacts with HCN to give $C_2H_5CH(OH)C_2H_5$, a non-chiral product. Statement 3 is incorrect as 2-chlorobutane will have no reaction with unionised HCN.

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CHEMISTRY

Paper 9701/12
Multiple Choice

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

General Comments

This examination paper provided a suitable challenge to the candidates. There were many pleasing performances, with a significant number of really good ones.

Twenty 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 1, 3, 4, 6, 7, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21, 23, 27, 28, 30, 31, 32, 33, 36, 37** and **39**. Since questions **36**, **37** and **39** are on this list it can be suggested that most candidates found they had sufficient time to complete the paper properly.

Five questions can be said to have been found to be particularly difficult. 35% or less of candidates chose the correct responses to each of **Questions 5, 20, 22, 29**, and **34**.

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Comments on Specific Questions

Question 5.

33% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. It can therefore be assumed that most candidates knew that initially the rate would increase, as catalyst was produced. However the correct answer is **C** as eventually reactants will get used up and the rate will decrease.

Question 20.

35% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 37% of candidates. The first and third reactions are oxidations which involve loss of hydrogen only, so they are not addition, substitution or reduction reactions. Therefore the question rests on the second reaction, in which ethanal and ethanol add to give a single product. The reaction is analogous to the addition of HCN to ethanal, therefore the answer is **B**. This is a difficult question but it can be answered by careful application of reactions studied in this course.

Question 22.

23% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 49% of candidates. Although the question looks very complicated it actually rests on one fact; a C=C double bond is not oxidised by $H^+/Cr_2O_7^{2-}$. Candidates who chose **D** were probably confusing the use of an excess of hot $H^+/Cr_2O_7^{2-}$ with the use of an excess of hot H^+/MnO_4^-.

Question 29.

20% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 47% of candidates. It could be that candidates who thought the answer was **B**, i.e. two of the four compounds, realised that the two carboxylic acids would react with sodium hydroxide to give salts. However they did not realise that the two esters would be hydrolysed, giving an alcohol and a sodium salt of a carboxylic acid in each case.

Question 34.

34% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 33% of candidates. Answer **A** was chosen by candidates who knew that statements 1, 2 and 3 were correct, answer **B** was chosen by candidates who believed that only statements 1 and 2 were correct. Therefore it can be deduced that this question rested for many on the truth or otherwise of statement 3. Statement 3 says “The activation energy is unchanged”. An increase in temperature will not change the activation energy of the reaction, so statement 3 is true.

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CHEMISTRY

Paper 9701/13
Multiple Choice

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

General Comments

This examination paper was found to be quite accessible but still provided a suitable challenge to the candidates. There were many pleasing performances, with a significant number of really good ones.

Nineteen questions can be said to have been found to be easier. 65% or more of candidates chose the correct responses to each of **Questions 2, 4, 5, 7, 8, 9, 11, 12, 13, 14, 18, 19, 20, 23, 25, 28, 29, 37** and **40**. Since **Questions 37** and **40** are on this list it can be suggested that most candidates found they had sufficient time to complete the paper properly.

Five questions can be said to have been found to be particularly difficult. 50% or less of candidates chose the correct responses to each of **Questions 3, 15, 24, 33** and **39**.

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Comments on Specific Questions

Question 3.

34% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 43% of candidates. Candidates who answered **C** may have decided that since T*l* is oxidised from +1 to +3, V must be reduced from +5 to +3. This approach ignores the volumetric data in the question. It can be deduced that when three moles of T*l* is oxidised from +1 to +3 (losing six moles of electrons), two moles of V is reduced. If two moles of V in the +5 oxidation state gains six moles of electrons it will be reduced to the +2 oxidation state.

Question 15.

43% of candidates chose the correct answer, **B**. The three remaining options were chosen by approximately equal numbers of candidates. An aqueous solution of ammonia, commonly called "ammonium hydroxide" contains ammonia molecules and ammonium ions. Being basic relative to water, ammonia molecules will receive H^+ ions to form ammonium ions, but will not donate H^+ ions to form amide ions.

Question 24.

37% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was B, chosen by 28% of candidates. Alcoholic KOH will react with 2-chlorobutane to produce but-1-ene, *cis*-but-2-ene, and *trans*-but-2-ene, hence the answer is three. Candidates who chose **B** may have been ignoring the but-1-ene, may not have known that but-2-ene has *cis-trans* isomers, or may have thought that the reaction was a substitution producing two optical isomers.

Question 33.

33% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 48% of candidates. Answer **D** means that only statement 1 is a correct answer to the question. Answer **B** means that statements 1 and 2 are correct answers to the question. Therefore this question rests whether or not statement 2 is a correct answer to the question. Statement 2 is true but it is <u>not</u> an answer to the question. The question is about acidity, and hydrogen atoms bonded directly to carbon atoms are not acidic.

Question 39.

46% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 35% of candidates. Answer **D** means that only statement 1 is true. Answer **B** means that statements 1 and 2 are true. Therefore this question rests on the truth or otherwise of statement 2. The ester in the question is propyl propanoate. This ester can be made using a sequence of reactions using propanal as the only organic material. Propanal can be reduced to propan-1-ol by $NaBH_4$. Propanal can be oxidised to propanoic acid by $H^+/Cr_2O_7^{2-}$. Propan-1-ol and propanoic acid can react together to give propyl propanoate, so statements 1 and 2 are both true.

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CHEMISTRY

Paper 9701/21
AS Structured Questions

Key Messages

Candidates are again to be reminded to read questions carefully and check their answers thoroughly. Candidates would have benefitted from this particularly in **Question 1(a)** where hydrogen-containing compounds were not always given, **Question 3(a)** where state symbols were often omitted and in the frequent use of non-chemical names in **Question 5(b)(i)**,

Candidates need to ensure that they are confident about the differences between structural, displayed and skeletal formula as asked in **Questions 4(d)**, **(e)** and **(f)**. Information about these different formulae is given in ***section 10.1*** of the syllabus.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Numerical answers are expected to be given to an appropriate number of significant figures – see syllabus ***section 1(h)*** – and to show correct units where appropriate.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Level chemistry syllabus. The overall standard achieved by candidates was very similar to that of last year, with most candidates showing some positive achievement. Candidates should be reminded that Chemistry has a significant factual content and some questions asked candidates to recall knowledge which they were not able to demonstrate.

Comments on Specific Questions

Question 1

A good understanding of Valence Shell Electron Pair Repulsion Theory (VSEPR) is important when studying AS level chemistry because it helps candidates to appreciate the shapes of simple molecules. This question on VSEPR was well answered by many candidates, most of whom gave correct structures and clear 'dot-and-cross' diagrams.

(a) This part was generally well answered. Some candidates incorrectly thought that the shape of the ammonia molecule was tetrahedral while others gave its shape as pyramidal rather than trigonal pyramidal. However, a significant number of candidates did not read the question carefully and gave compounds which did not contain hydrogen, despite the instruction in the question.

(b) (i) The majority of candidates gave a correct diagram in this part. A small number omitted the lone pairs of the fluorine atoms while a larger number gave structures with bonding pairs between the fluorine atoms.

(ii) This was correctly answered by most candidates.

(iii) This too was usually correctly answered.

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Question 2

The ability to predict the shapes of molecules produced in chemical reactions is another important skill. There were fewer fully correct answers to this question with many candidate not able to give three correct structures in **(b)(ii)**.

(a) The majority of candidates gave an answer in the range 117 - 120° which Examiners accepted.

(b) (i) This was less well answered with many candidates incorrectly stating that this is an example of a nucleophilic rather than an electrophilic addition.

(ii) While there were many fully correct answers, a significant number of candidates struggled to provide three different cyclic compounds. One common mistake was to give at least one structure which was a di-chlorinated isomer of propene, rather than cyclopropane.

Question 3

This question tested candidates' knowledge of some important aspects of the chemistry of chlorine and its compounds. A large number of candidates seemed to be unfamiliar with these reactions.

(a) (i) While there were many half-equations containing the correct species, a significant number of answers did not include state symbols, as requested.

(ii) This part was quite well answered although some candidates did not seem to know that iron will react with chlorine.

(b) There were many incorrect observations given here; the physical state of the colourless liquid, PCl_3, and the white solid, PCl_5, being regularly incorrect. A small number of answers also contained incorrect equations which either used Cl rather than Cl_2 as the reagent, or were unbalanced.

(c) The reactions of chlorine with hot and cold aqueous sodium hydroxide are specifically referred to in ***section 9.4(h)*** in the syllabus. Despite this, many candidates did not give a correct compound for either condition.

(d) There were some very good answers to this part but many candidates did not make clear the essential difference between the behaviour of the two chlorides in water. The reaction between silicon tetrachloride and water was generally well understood but relatively few candidates stated clearly that magnesium chloride does not react with water. Many thought it 'reacted' with water to make the hydroxide and HCl.

Question 4

Chemical calculations test a candidate's ability to use appropriate expressions and to handle data correctly with the use of suitable units. This first set of calculations on the paper was well answered by many candidates, most of whom were able to deduce the identity of the acid **R**. Fewer candidates showed good knowledge of the organic reactions involved in later parts of the question.

(a) The five steps in this part enabled many candidates to calculate the correct M_r of the acid **R**. The numerical answers to **(ii)** to **(v)** are given below.

(i) The majority of candidates gave a correct equation. The most common error was to give the formula of the product as NaX which usually led to incorrect stoichiometry in the equation.

(ii)-(v) These calculations were generally well executed.

(b) (i) Although there were many fully correct answers to this part, there were candidates who did not calculate all three M_r values correctly.

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(ii) Those candidates who had answered **(a)(v)** correctly experienced no difficulties with this part, correctly identifying compound **S** as the acid.

However, many of those candidates who had given a wrong equation in **(a)(i)** calculated the M_r of **R** to be 58 rather than 116. They then did not appreciate that the discrepancy between the two was too great and guessed at compound **S** with no supporting evidence for it. Only a very small number made any attempt to try to find out where they had gone wrong.

(c) Relatively few candidates knew the reagents and conditions for each of the three reactions given in the question. Often the identity of the reagent was ambiguous; e.g. potassium manganate rather than potassium manganate(VII) for example. Sometimes conditions were contradictory, such as 'cold $KMnO_4$ under reflux'.

(d) In this part candidates had to know with which of the functional groups in the two compounds the individual reagents would react. Many struggled here; often with the –OH group in the middle of compound **T** being left unreacted with sodium or with both of the central –OH groups of compound **U** reacting with sodium carbonate.

(e) While there were many correct *cis-trans* isomers given, many structures were badly drawn; e.g. an oxygen atom of one of the carboxylic acid groups incorrectly attached to one of the carbon atoms of the >C=C< bond.

(f) Relatively few candidates gave a correct structure for the cyclic compound **V**. Those candidates who deduced that the reaction involved dehydration and ring closure are to be congratulated.

Question 5

The early parts of this question elicited some good answers. However, the same was not true of **(d)** and **(e)**. In the former there were many incorrect answers, usually caused by poor substitution into well-known expressions. The last part saw some very ambiguous answers with many candidates confusing intermolecular forces and intramolecular bonds.

(a) (i) This part was correctly answered by the majority of candidates.

(ii) Equations in this part were usually completely correct.

(b) (i) This part was less well answered with many candidates apparently ignoring the phrase 'black solid' when giving their answer.

(ii) In this part, Examiners required an equation that had C (the black solid) as a product. A significant number of candidates gave CO as their only product of incomplete combustion and were given no credit.

(c) While many candidates gave fully correct answers, there was a significant number of responses which were either incomplete or ambiguous. Definitions of terms used in chemical thermodynamics must be accurately stated. Examiners did not accept answers that included the phrase 'It is the energy required...' because combustion is always an exothermic process.

(d) (i) In this part, many candidates did not correctly substitute the data contained in the question into the equation $pV = nRT$. The most common mistakes involved the conversion of the volume from cm^3 into m^3 or of the pressure from kPa into Nm^{-2}. A smaller number of candidates used an incorrect value in their calculation, generally because they did not convert the temperature to 293 K.

(ii) Many candidates did not make correct substitutions into the equation heat released = $m\,c\,\delta T$. The most common error was to use an incorrect temperature, either by not using the value of the temperature change given in the question or by converting it from degrees Celsius to Kelvin. A smaller number used an incorrect mass; often the mass calculated in **(i)** rather than the 200 g given in the question.

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A small, but significant, number of candidates attempted to perform this calculation by using bond energy values from the *Data Booklet* rather than the expression given above. The use of such an inappropriate method will receive no credit.

(iii) In this part, candidates were expected to use their answers from **(i)** and **(ii)**. The majority did this successfully and Examiners gave full credit to those candidates who had incorrect answers in earlier parts but carried out this process correctly. The single most common error in this part was to give incorrect units, for example J instead of kJ or vice versa.

(e) Many candidates struggled to give a clear explanation of the information given in the question. As is often the case, some candidates incorrectly thought that the differences depended on the relative strengths of different chemical bonds. Many answers included ambiguous statements about the breaking of 'bonds' without making it absolutely clear whether these were covalent bonds within molecules or forces between molecules.

(i) When considering the four compounds as a group it is apparent that the boiling point increases with the size of the straight chain molecule. It is clear that the number of electrons in each molecule increases from methane to butane and, as a result, the electron charge cloud around the molecule has a greater capacity to form a dipole. Thus, it may be deduced that the strengths of the induced dipole-induced dipole interactions between the molecules – van der Waals' forces - increase with the increase in the size of the molecules.

(ii) Many candidates struggled to give a clear explanation of the differences in boiling point given in the question. The molecules of straight chain hydrocarbons such as butane are able to pack together more closely than those of a branched chain hydrocarbon such as 2-methylpropane. As van der Waals' forces are weak, the distance between molecules has a significant effect on their strength and hence on the boiling point.

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CHEMISTRY

Paper 9701/22
AS Structured Questions

Key Messages

Candidates are again to be reminded to read questions carefully and check their answers thoroughly. Candidates would have benefitted from this particularly in **Question 1(a)** where hydrogen-containing compounds were not always given, **Question 3(a)** where state symbols were often omitted and in the frequent use of non-chemical names in **Question 5(b)(i)**,

Candidates need to ensure that they are confident about the differences between structural, displayed and skeletal formula as asked in **Questions 4(d)**, **(e)** and **(f)**. Information about these different formulae is given in ***section 10.1*** of the syllabus.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Numerical answers are expected to be given to an appropriate number of significant figures – see syllabus ***section 1(h)*** – and to show correct units where appropriate.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of the AS Level chemistry syllabus. The overall standard achieved by candidates was very similar to that of last year, with most candidates showing some positive achievement. Candidates should be reminded that Chemistry has a significant factual content and some questions asked candidates to recall knowledge which they were not able to demonstrate.

Comments on Specific Questions

Question 1

A good understanding of Valence Shell Electron Pair Repulsion Theory (VSEPR) is important when studying AS level chemistry because it helps candidates to appreciate the shapes of simple molecules. This question on VSEPR was well answered by many candidates, most of whom gave correct structures and clear 'dot-and-cross' diagrams.

(a) This part was generally well answered. Some candidates incorrectly thought that the shape of the ammonia molecule was tetrahedral while others gave its shape as pyramidal rather than trigonal pyramidal. However, a significant number of candidates did not read the question carefully and gave compounds which did not contain hydrogen, despite the instruction in the question.

(b) (i) The majority of candidates gave a correct diagram in this part. A small number omitted the lone pairs of the fluorine atoms while a larger number gave structures with bonding pairs between the fluorine atoms.

(ii) This was correctly answered by most candidates.

(iii) This too was usually correctly answered.

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Question 2

The ability to predict the shapes of molecules produced in chemical reactions is another important skill. There were fewer fully correct answers to this question with many candidate not able to give three correct structures in **(b)(ii)**.

(a) The majority of candidates gave an answer in the range 117 - 120° which Examiners accepted.

(b) (i) This was less well answered with many candidates incorrectly stating that this is an example of a nucleophilic rather than an electrophilic addition.

(ii) While there were many fully correct answers, a significant number of candidates struggled to provide three different cyclic compounds. One common mistake was to give at least one structure which was a di-chlorinated isomer of propene, rather than cyclopropane.

Question 3

This question tested candidates' knowledge of some important aspects of the chemistry of chlorine and its compounds. A large number of candidates seemed to be unfamiliar with these reactions.

(a) (i) While there were many half-equations containing the correct species, a significant number of answers did not include state symbols, as requested.

(ii) This part was quite well answered although some candidates did not seem to know that iron will react with chlorine.

(b) There were many incorrect observations given here; the physical state of the colourless liquid, PCl_3, and the white solid, PCl_5, being regularly incorrect. A small number of answers also contained incorrect equations which either used Cl rather than Cl_2 as the reagent, or were unbalanced.

(c) The reactions of chlorine with hot and cold aqueous sodium hydroxide are specifically referred to in ***section 9.4(h)*** in the syllabus. Despite this, many candidates did not give a correct compound for either condition.

(d) There were some very good answers to this part but many candidates did not make clear the essential difference between the behaviour of the two chlorides in water. The reaction between silicon tetrachloride and water was generally well understood but relatively few candidates stated clearly that magnesium chloride does not react with water. Many thought it 'reacted' with water to make the hydroxide and HCl.

Question 4

Chemical calculations test a candidate's ability to use appropriate expressions and to handle data correctly with the use of suitable units. This first set of calculations on the paper was well answered by many candidates, most of whom were able to deduce the identity of the acid **R**. Fewer candidates showed good knowledge of the organic reactions involved in later parts of the question.

(a) The five steps in this part enabled many candidates to calculate the correct M_r of the acid **R**. The numerical answers to **(ii)** to **(v)** are given below.

(i) The majority of candidates gave a correct equation. The most common error was to give the formula of the product as NaX which usually led to incorrect stoichiometry in the equation.

(ii)-(v) These calculations were generally well executed.

(b) (i) Although there were many fully correct answers to this part, there were candidates who did not calculate all three M_r values correctly.

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(ii) Those candidates who had answered **(a)(v)** correctly experienced no difficulties with this part, correctly identifying compound **S** as the acid.

However, many of those candidates who had given a wrong equation in **(a)(i)** calculated the M_r of **R** to be 58 rather than 116. They then did not appreciate that the discrepancy between the two was too great and guessed at compound **S** with no supporting evidence for it. Only a very small number made any attempt to try to find out where they had gone wrong.

(c) Relatively few candidates knew the reagents and conditions for each of the three reactions given in the question. Often the identity of the reagent was ambiguous; e.g. potassium manganate rather than potassium manganate(VII) for example. Sometimes conditions were contradictory, such as 'cold $KMnO_4$ under reflux'.

(d) In this part candidates had to know with which of the functional groups in the two compounds the individual reagents would react. Many struggled here; often with the –OH group in the middle of compound **T** being left unreacted with sodium or with both of the central –OH groups of compound **U** reacting with sodium carbonate.

(e) While there were many correct *cis-trans* isomers given, many structures were badly drawn; e.g. an oxygen atom of one of the carboxylic acid groups incorrectly attached to one of the carbon atoms of the >C=C< bond.

(f) Relatively few candidates gave a correct structure for the cyclic compound **V**. Those candidates who deduced that the reaction involved dehydration and ring closure are to be congratulated.

Question 5

The early parts of this question elicited some good answers. However, the same was not true of **(d)** and **(e)**. In the former there were many incorrect answers, usually caused by poor substitution into well-known expressions. The last part saw some very ambiguous answers with many candidates confusing intermolecular forces and intramolecular bonds.

(a) (i) This part was correctly answered by the majority of candidates.

(ii) Equations in this part were usually completely correct.

(b) (i) This part was less well answered with many candidates apparently ignoring the phrase 'black solid' when giving their answer.

(ii) In this part, Examiners required an equation that had C (the black solid) as a product. A significant number of candidates gave CO as their only product of incomplete combustion and were given no credit.

(c) While many candidates gave fully correct answers, there was a significant number of responses which were either incomplete or ambiguous. Definitions of terms used in chemical thermodynamics must be accurately stated. Examiners did not accept answers that included the phrase 'It is the energy required...' because combustion is always an exothermic process.

(d) (i) In this part, many candidates did not correctly substitute the data contained in the question into the equation $pV = nRT$. The most common mistakes involved the conversion of the volume from cm^3 into m^3 or of the pressure from kPa into Nm^{-2}. A smaller number of candidates used an incorrect value in their calculation, generally because they did not convert the temperature to 293 K.

(ii) Many candidates did not make correct substitutions into the equation heat released = $m\,c\,\delta T$. The most common error was to use an incorrect temperature, either by not using the value of the temperature change given in the question or by converting it from degrees Celsius to Kelvin. A smaller number used an incorrect mass; often the mass calculated in **(i)** rather than the 200 g given in the question.

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A small, but significant, number of candidates attempted to perform this calculation by using bond energy values from the *Data Booklet* rather than the expression given above. The use of such an inappropriate method will receive no credit.

(iii) In this part, candidates were expected to use their answers from **(i)** and **(ii)**. The majority did this successfully and Examiners gave full credit to those candidates who had incorrect answers in earlier parts but carried out this process correctly. The single most common error in this part was to give incorrect units, for example J instead of kJ or vice versa.

(e) Many candidates struggled to give a clear explanation of the information given in the question. As is often the case, some candidates incorrectly thought that the differences depended on the relative strengths of different chemical bonds. Many answers included ambiguous statements about the breaking of 'bonds' without making it absolutely clear whether these were covalent bonds within molecules or forces between molecules.

(i) When considering the four compounds as a group it is apparent that the boiling point increases with the size of the straight chain molecule. It is clear that the number of electrons in each molecule increases from methane to butane and, as a result, the electron charge cloud around the molecule has a greater capacity to form a dipole. Thus, it may be deduced that the strengths of the induced dipole-induced dipole interactions between the molecules – van der Waals' forces - increase with the increase in the size of the molecules.

(ii) Many candidates struggled to give a clear explanation of the differences in boiling point given in the question. The molecules of straight chain hydrocarbons such as butane are able to pack together more closely than those of a branched chain hydrocarbon such as 2-methylpropane. As van der Waals' forces are weak, the distance between molecules has a significant effect on their strength and hence on the boiling point.

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CHEMISTRY

Paper 9701/23
AS Structured Questions

Key Messages

Candidates are again to be reminded to read questions carefully and check their answers thoroughly. Candidates would have benefitted from this particularly in **Question 2(b)(i)** where formulae of products rather than names were often given and in **Question 2(b)(iii)** the incorrect use of C_9H_{20} (petrol) as the fuel used in the equation rather than $C_{14}H_{30}$ (diesel) as the question required.

Candidates need to ensure that they are confident about the differences between structural, displayed and skeletal formula as asked in **Question 5(a)**, where carbon atoms, C, appeared in many of the skeletal formulae drawn by candidates. Information about these different formulae is given in ***section 10.1*** of the syllabus.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Numerical answers are expected to be given to an appropriate number of significant figures – see syllabus ***section 1(h)*** – and to show correct units when required.

General Comments

This paper tested candidate's knowledge and understanding of important aspects of AS Level chemistry. The overall standard achieved by candidates was similar to that of last year with a sound knowledge of organic chemistry shown by many candidates.

Comments on Specific Questions

Question 1

This question required a knowledge and understanding of the intermolecular and intramolecular bonding in ammonia and ammonium chloride. Many candidates struggled to provide clear, unambiguous answers.

(a) Candidates generally gave correct 'dot-and-cross' diagrams but many gave the shape of ammonia as planar, although they had included the lone pair of electrons in the diagram. Other candidates thought, incorrectly, that the shape of the ammonia molecule was tetrahedral while a small number gave its shape as pyramidal rather than trigonal pyramidal.

(b) This part required candidates to consider the properties of two well-studied compounds from a slightly unusual perspective. Many candidates struggled to give clear explanations.

(i) The meaning of the term *bond polarity* was not well understood by the majority of candidates. Examiners expected candidates to state that nitrogen and hydrogen have different electronegativities and, as a result, the bonding pair of electrons will be shared unequally.

(ii) The concept of a molecule being polar also caused many candidates problems with relatively few correct answers. In the case of methane, the symmetry of the molecule means that it does not have a net dipole. The ammonia molecule, on the other hand, is not symmetrical and does have a dipole.

(iii) This part saw some better answers with many candidates referring to the solubility of ammonia in water. Some candidates mentioned the 'high boiling point of ammonia' but without any reference to the boiling point of methane. Without a suitable comparison, Examiners did not give such answers any credit.

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(c) This question caused many candidates a problem. The straightforward answer given by more able candidates was three covalent bonds, one co-ordinate (dative) bond and one ionic bond. A significant number of candidates wrongly thought hydrogen bonding was present in ammonium chloride.

Question 2

Chemical calculations test a candidate's ability to use appropriate expressions and to handle data correctly with the use of suitable units. This first set of calculations on the paper was well answered by many candidates, most of whom were able to carry out the calculation correctly.

(a) (i) This was correctly answered by almost all candidates.

(ii) The majority of candidates gave a fully correct equation.

(b) (i) This part was less well done with many answers containing oxides of nitrogen or of sulfur which did not arise from the incomplete combustion of a hydrocarbon fuel. Some candidates gave formulae rather than names as the question required and were given no credit for their answers.

(ii) This was generally well answered with many candidates showing good knowledge of the hazards that can exist.

(iii) In this part there were many correct equations given. Examiners accepted equations producing C or CO or both.

(c) While many candidates gave fully correct answers, there was a significant number of answers which were either incomplete or ambiguous. Definitions of terms used in chemical thermodynamics must be accurately stated. Examiners did not accept answers that included the phrase 'It is the energy required...' because combustion is always an exothermic process.

(d) (i) This part saw many candidates making correct substitutions into the equation, heat released = $mc\delta T$. The most common error was to use an incorrect temperature by converting the temperature change given in the question from 34.6 °C into 307.6 K.

(ii) Many candidates used the information given in the question and their answer to **(i)** correctly.

Question 3

This question tested candidates' knowledge of some important aspects of the chemistry of chlorine and its compounds. A large number of candidates struggled with parts of this question, experiencing some difficulty in applying their knowledge and understanding to the unfamiliar compound BrC*l*.

(a) (i) This part was well answered by many candidates. One common incorrect answer was to state that solid iodine is purple. The solid is grey and the vapour is purple.

(ii) While there were many good answers to this part, there was still a number of candidates who either referred to the strengths of the chemical bonds within the molecules or simply referred to the change in size of the molecules.

When considering the three elements as a group it is apparent that the melting point increases with the size of the molecule. It is clear that the number of electrons in each molecule increases from chlorine to iodine and, as a result, the electron charge cloud around the molecule has a greater capacity to form a dipole. Thus, it may be deduced that the strengths of the induced dipole-induced dipole interactions between the molecules – van der Waals' forces - increase with the increase in the size of the molecules.

(b) (i) This was well answered with very few incorrect configurations.

(ii) This too was well answered with very few incorrect 'dot-and-cross' diagrams.

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(c) (i) Many candidates struggled with this part. It was expected that candidates could deduce that BrC*l* was a gas or a liquid. Only the more able candidates could explain that this was due to BrC*l* having fewer electrons than Br_2 and thus having weaker van der Waals' forces.

(ii) Examiners expected candidates to consider the colours of bromine and chlorine and predict a colour in the range yellow – orange – red - brown. Many did this but there were some who gave unusual predictions such as 'purple'.

(d) (i) Many candidates did not answer this question well. Initially a yellow/brown colour is seen, followed later by the production of solid iodine, i.e. grey/black - but not purple.

(ii) There were many correct answers to this part.

(iii) Only the more able candidates correctly deduced the correct equation for this reaction.

(iv) The majority of candidates deduced that Cl_2 and BrC*l* had both acted as oxidising agents.

Question 4

The majority of candidates coped well with the calculations in this question. However, answers to the questions on organic chemistry were often less good. As a result, only a minority of candidates correctly identified compound **Q**.

(a) (i) This was correctly answered by the majority of candidates who gave structural or functional group isomerism as their answer.

(ii) In this part full names of the functional groups were requested so primary alcohol and carboxylic acid were expected as appropriate. Not all candidates gave these.

(iii) Those candidates who had revised thoroughly coped well with this part, knowing that only carboxylic acids react with sodium carbonate.

(iv) As in the previous part, thorough revision enabled candidates to say that alcohols and carboxylic acids will react with sodium metal.

(b) These parts were well answered by many candidates.

(c) These parts were well also answered by many candidates.

(d) Only the more able candidates realised that compound **Q** was isomer **R** as the only isomer to react with both sodium carbonate and sodium metal. The equations were well done by these candidates although some spoiled wrote unbalanced equations.

Question 5

This question tested candidates' ability to draw skeletal and structural formulae. As has already been mentioned, this continues to be a problem for some.

(a) This part received many incorrect answers. Some candidates introduced extra carbon atoms - as C – while others joined their atoms incorrectly with the sequence O–H–C often implied in their structure.

(b) Many candidates gained full credit here. The most common error was giving the products of **W** and **Y** as aldehydes despite the information that the alcohol was heated under reflux with the oxidising agent.

(c) In this part, the more able candidates realised alcohol **X**, the only secondary alcohol, produced three organic products (but-1-ene and the *cis-trans* isomers of but-2-ene) and gave two of these as structural formulae.

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CHEMISTRY

Paper 9701/31
Advanced Practical Skills1

Key Messages

- Instructions in the rubric need to be read and acted upon, such as recording all data specified.
- Candidates should be aware that mass and weight are not synonymous.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General Comments

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

This paper proved accessible to most candidates. Almost all candidates completed the paper, indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Almost all of the candidates completed the practical work and were able to gain credit for accuracy and in the calculation. This question was answered well by a large majority of candidates.

(a) Candidates should be reminded to record burette readings for the rough titration, even though these do not need to be to the same level of precision as those generating values for the accurate titres. Most candidates supplied the balance readings and mass of **FA 1** used, as well as giving correct headings and units. However, there was a significant minority of candidates who did not record accurate burette readings to 0.05 cm^3 or did not have concordant titres.

(b) The majority of candidates calculated a suitable value of the volume of **FA 4** to be used in the calculation, with few selecting titres with a spread of more than 0.20 cm^3. Some candidates rounded the value to the nearest 0.05 cm^3 or to 1 decimal place. Candidates should be reminded that they must indicate which titres they are using in their calculation.

(c)(i) to (v)
Many candidates gained full credit for the calculation. The majority gave all final answers to 3 or 4 significant figures. However, only a minority were able to write an appropriate half equation in part **(ii).** The most common error was to put the electron on the wrong side; others included incorrect balancing and the use of reversible arrows when the question specified that Fe^{2+} was oxidised to Fe^{3+}.

(d) (i) This was generally well answered.

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(ii) Few candidates gained credit, as they often did not double the maximum error where two balance readings were taken, to find the mass of the beaker.

(iii) The maximum percentage error was calculated correctly by some candidates.

Question 2

Candidates should be encouraged to draw up results tables in advance of collecting data, as this will aid them in recording all the required items clearly. Those only attempting one of the two experiments were unable to access several of the marks.

(a) Most candidates used masses of **FA** 5 in the ranges specified and recorded all masses to the same number of decimal places. However, fewer candidates gained credit for suitable headings, although almost all displayed the unit correctly. The majority were able to gain partial credit for accuracy references.

(b) (i) The majority of candidates answered this correctly.

(ii) Fewer candidates gained credit for this part. The most common errors were using the masses of hydrated barium chloride or using a wrongly subtracted value for the mass of anhydrous salt.

(iii) Although a substantial minority gained partial credit, many did not give answers to the nearest whole number.

(c)(i) The most commonly awarded mark was for candidates specifying heating to constant mass in, indicating that they were familiar with this type of procedure. Weaker candidates suggested using a lid or heating for a longer time.

(ii) Only the more able candidates calculated a ratio or scale factor, while weaker candidates left it blank. Many simply compared the masses or moles of water lost in the two experiments, expecting them to be equal.

Question 3

Careful reading of the instructions was needed for the tests to be carried out correctly. Candidates should be prepared to report more than one observation per test carried out.

(a)(i) Many candidates were awarded partial credit. The common errors were reporting a grey-green precipitate in the first test and/or not giving observations for both a small volume of and excess NaOH(aq). A sizable minority gained the mark for observing a gas turning damp red litmus blue on heating the solution of **FA** 6 with NaOH(aq). The most commonly awarded mark was for the white precipitate being insoluble in HC*l*(aq) in the second test.

(ii) Owing to incorrect observations, few candidates gained the mark for Cr^{3+} and a variety of incorrect anions were suggested.

(iii) Credit was seldom awarded, usually because the ionic equation was not balanced. Some candidates appeared confused as to the product of the reaction.

(iv) The question instructed candidates to heat gently, then strongly so at least two observations were expected. Few observed condensation at the mouth of the tube, though a small number stated water of crystallisation was present. However, the latter is a deduction so could not be credited. The most frequently seen correct response was that **FA** 6 formed a gas which turned red litmus blue on strong heating.

(b) The instruction to identify gases released by a test was ignored by many, even though almost all candidates correctly reported fizzing, bubbles or effervescence on adding **FA** 3 to **FA** 7. The tests with **FA** 8 were carried out well and the correct observations recorded, though a minority wrote of 'white solutions'. It is important to indicate changes of appearance on carrying out a test, so 'orange solution' alone could not be credited for **FA** 3 with **FA** 9. A large minority gained the mark for observations with **FA** 9. The marks for identifying the ions specified were awarded to many, as at least one observation per unknown solution was usually correct. The most common incorrect deductions were Mg^{2+} for **FA** 8 and I^- for **FA** 9, and some candidates confused anions and cations.

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CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Instructions in the rubric need to be read and acted upon, such as recording all data specified.
- Candidates should be aware that mass and weight are not synonymous.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General Comments

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

This paper proved accessible to most candidates. Almost all candidates completed the paper, indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Almost all of the candidates completed the practical work and were able to gain credit for accuracy and in the calculation. This question was answered well by a large majority of candidates.

(a) Candidates should be reminded to record burette readings for the rough titration, even though these do not need to be to the same level of precision as those generating values for the accurate titres. Most candidates supplied the balance readings and mass of **FA 1** used, as well as giving correct headings and units. However, there was a significant minority of candidates who did not record accurate burette readings to 0.05 cm^3 or did not have concordant titres.

(b) The majority of candidates calculated a suitable value of the volume of **FA 4** to be used in the calculation, with few selecting titres with a spread of more than 0.20 cm^3. Some candidates rounded the value to the nearest 0.05 cm^3 or to 1 decimal place. Candidates should be reminded that they must indicate which titres they are using in their calculation.

(c)(i) to (v)
Many candidates gained full credit for the calculation. The majority gave all final answers to 3 or 4 significant figures. However, only a minority were able to write an appropriate half equation in part **(ii).** The most common error was to put the electron on the wrong side; others included incorrect balancing and the use of reversible arrows when the question specified that Fe^{2+} was oxidised to Fe^{3+}.

(d)(i) This was generally well answered.

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(ii) Few candidates gained credit, as they often did not double the maximum error where two balance readings were taken, to find the mass of the beaker.

(iii) The maximum percentage error was calculated correctly by some candidates.

Question 2

Candidates should be encouraged to draw up results tables in advance of collecting data, as this will aid them in recording all the required items clearly. Those only attempting one of the two experiments were unable to access several of the marks.

(a) Most candidates used masses of **FA** 5 in the ranges specified and recorded all masses to the same number of decimal places. However, fewer candidates gained credit for suitable headings, although almost all displayed the unit correctly. The majority were able to gain partial credit for accuracy references.

(b) (i) The majority of candidates answered this correctly.

(ii) Fewer candidates gained credit for this part. The most common errors were using the masses of hydrated barium chloride or using a wrongly subtracted value for the mass of anhydrous salt.

(iii) Although a substantial minority gained partial credit, many did not give answers to the nearest whole number.

(c)(i) The most commonly awarded mark was for candidates specifying heating to constant mass in, indicating that they were familiar with this type of procedure. Weaker candidates suggested using a lid or heating for a longer time.

(ii) Only the more able candidates calculated a ratio or scale factor, while weaker candidates left it blank. Many simply compared the masses or moles of water lost in the two experiments, expecting them to be equal.

Question 3

Careful reading of the instructions was needed for the tests to be carried out correctly. Candidates should be prepared to report more than one observation per test carried out.

(a)(i) Many candidates were awarded partial credit. The common errors were reporting a grey-green precipitate in the first test and/or not giving observations for both a small volume of and excess NaOH(aq). A sizable minority gained the mark for observing a gas turning damp red litmus blue on heating the solution of **FA** 6 with NaOH(aq). The most commonly awarded mark was for the white precipitate being insoluble in HC*l*(aq) in the second test.

(ii) Owing to incorrect observations, few candidates gained the mark for Cr^{3+} and a variety of incorrect anions were suggested.

(iii) Credit was seldom awarded, usually because the ionic equation was not balanced. Some candidates appeared confused as to the product of the reaction.

(iv) The question instructed candidates to heat gently, then strongly so at least two observations were expected. Few observed condensation at the mouth of the tube, though a small number stated water of crystallisation was present. However, the latter is a deduction so could not be credited. The most frequently seen correct response was that **FA** 6 formed a gas which turned red litmus blue on strong heating.

(b) The instruction to identify gases released by a test was ignored by many, even though almost all candidates correctly reported fizzing, bubbles or effervescence on adding **FA** 3 to **FA** 7. The tests with **FA** 8 were carried out well and the correct observations recorded, though a minority wrote of 'white solutions'. It is important to indicate changes of appearance on carrying out a test, so 'orange solution' alone could not be credited for **FA** 3 with **FA** 9. A large minority gained the mark for observations with **FA** 9. The marks for identifying the ions specified were awarded to many, as at least one observation per unknown solution was usually correct. The most common incorrect deductions were Mg^{2+} for **FA** 8 and I^- for **FA** 9, and some candidates confused anions and cations.

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CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key Messages

- Instructions in the rubric need to be read and acted upon, such as recording all data specified.
- Candidates should be aware that mass and weight are not synonymous.
- Candidates should be encouraged to use the same balance for all their readings, so as to avoid any systematic errors.
- Conclusions and inferences must be drawn from the actual results of the tests carried out.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General Comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

This paper proved accessible to most candidates. Almost all candidates completed the paper, indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Almost all of the candidates completed the practical work and were able to gain credit for accuracy and parts of the calculation.

(a) Candidates should be reminded to record burette readings for the rough titration, even though these do not need to be to the same level of precision as those generating values for the accurate titres. There is a significant minority of candidates who do not record accurate burette readings to 0.05 cm^3 or do not have concordant titres.

(b) The majority of candidates calculated a suitable value of the volume of **FB 2** to be used in the calculation, with few selecting titres with a spread of more than 0.20 cm^3. Some rounded the value to the nearest 0.05 cm^3 or to 1 decimal place. Candidates should be reminded that they must indicate which titres they are using in their calculation.

(c)(i) and **(iii)**
Most candidates were able to gain partial credit for parts **(i)** to **(iii).**

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(iv) and **iv)**

While most candidates were able to use 106 correctly, some divided by 2 or used their answer to **(i)** in part **(v)**.

(vi) Part **(vi)** proved challenging to most candidates. Although most multiplied by 40, many candidates used their answer to **(v)** or if the titre was unusually low, used **(v)** – **(i)** to avoid negative values.

(vii) This was well answered, to the extent that almost every candidate had an idea that it must involve the ratio of one mass to another, expressed as a percentage. A common error was not to divide by the total mass. Many candidates did quote their answer to the correct number of significant figures.

Question 2

Candidates should be encouraged to draw up results tables in advance of collecting data, as this will aid them in recording all the required items clearly. The calculation and error/improvement sections proved challenging for many candidates.

(a) Credit for the consistency in recording the four balance readings and masses of **FB** 4 and CO_2 was frequently awarded. However, fewer candidates gave appropriate headings for all data. The most common error was in recording the final mass of the flask omitting 'contents'. Most displayed the unit for mass correctly. Those who had included extra balance readings were less likely to calculate the mass of CO_2 correctly. Although the majority of candidates gained credit for the calculation of the two masses. Candidates should be encouraged to check their working as some calculated a mass of CO_2 in excess of the mass of **FB** 4. The majority of candidates were awarded some credit for accuracy, although agreement between candidate and Supervisor was generally poorer than in the titration question.

(b) (i) and (ii)

Many candidates began this part incorrectly, as they calculated the number of moles of acid forgetting that this was in excess. This usually led to inverting the mass ratio in **(ii)** to avoid percentages of over 100%. Some candidates, while approaching the question correctly, rounded the moles of CO_2 inappropriately, so that on multiplying by 106 the mass of Na_2CO_3 was arithmetically incorrect. A significant minority were able to gain full credit.

(c)(i) to **(iii)**

This section proved challenging for most candidates. Some candidates did not appreciate that masses of chemicals were being used, so suggested measuring the acid with a burette instead of a measuring cylinder. The expected use of a cotton wool plug was not seen. As the CO_2 had to escape for the procedure to be valid, the commonly suggested use of a lid was also not appropriate. The most common correct responses were for some **FA** 4 to be stuck in the mouth of the conical flask, frothing/spitting of reactants, CO_2 remaining in solution and that insufficient time had elapsed for the solid to react completely. Candidates were rarely able to explain correctly the effect the stated error would have on the percentage by mass of Na_2CO_3. Some candidates suggested an improvement which bore no relation to the error identified in part **(i).** However, there were some excellent responses to this section with the parts following each other logically, indicating these candidates were well acquainted with this type of practical.

Question 3

Candidates should be reminded that gas tests should be carried out where effervescence is observed. Candidates should be prepared to report more than one observation per test carried out.

(a)(i) and **(ii)**

It was important for the development of the question that candidates followed the instruction of how much nitric acid to use with the solids. Most recorded effervescence with **FB** 5 and the few who tested the gas with limewater reported the correct result. Some candidates recorded difficulty in getting **FB** 6 to dissolve in the acid, so lost credit for the formation of a colourless solution. Lack of precision in technical terms cost a significant minority credit in **(ii).** There were many errors in the reporting of the colour of precipitates and their solubilities with excess alkali. It was important to add the alkalis until no further changes took place, as the solutions tested were acidic. Candidates should be encouraged to use the Qualitative Analysis Notes to find the correct terminology, as errors such as 'cloudy solution', instead of precipitate were seen. Almost all candidates noted the yellow precipitate with KI(aq) and **FB** 6, though fewer recorded the observation with **FB** 5 correctly.

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(iii) and **(iv)**

Most candidates identified Cu^{2+} in **FB** 5 and many were also able to identify Pb^{2+} in **FB** 6. Some ignored the yellow precipitate and suggested Al^{3+}, Mg^{2+} or Zn^{2+}. A significant minority gave reasons for identifying the cations, suggesting lack of careful reading of the question. Of those attempting to identify either of the anions present, the greater number gained credit for carbonate, citing effervescence or a successful limewater test in evidence. Some candidates gave no reasoning and some quoted a positive limewater test without having carried it out.

(b) (i) The majority of candidates were able to gain partial credit, with effervescence appearing most frequently. Those who reported testing the gas with a lighted splint and observing a 'pop' were awarded credit in **(a)** if they had not tested the gas in **(a)(i).** A number of those testing the gas in reported it turned red litmus blue or gave a white precipitate with limewater, so lost credit. Some lost the observation mark for $KMnO_4$, by reporting it dissolved or gave a clear solution. Few gained the conclusion mark, as they frequently omitted this section. Others wrote $KMnO_4$ is an oxidising agent, where the deduction should have been about **FB** 7.

(ii) Melting or dissolving was often reported, although few candidates appeared to heat sufficiently strongly to see charring of the solid and few noted the initial condensation.

(iii) This proved challenging for many candidates, with the more able suggesting the presence of a hydrated solid or that thermal decomposition took place. A few identified the solid as an organic compound.

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CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key Messages

- Instructions in the rubric need to be read and acted upon, such as recording all data specified.
- Candidates should be aware that mass and weight are not synonymous.
- Conclusions and inferences must be drawn from the actual results of the tests carried out.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

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This paper proved accessible to most candidates. Almost all candidates completed the paper, indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Almost all candidates completed the practical work and were able to gain credit for accuracy and in some parts of the calculation.

(a) Candidates should be reminded to record burette readings for the rough titration, even though these do not need to be to the same level of precision as for the accurate titres. There is a significant minority of candidates who do not record accurate burette readings to 0.05 cm^3 or do not have concordant titres. Concordant, in this context, means that two or more titres should be within 0.1 cm^3. Most candidates gained credit for the accuracy with which they carried out the titration.

(b) The majority of candidates calculated a suitable value of the volume of **FA 2** to be used in the calculation, with few selecting titres with a spread of more than 0.20 cm^3. Some rounded the value to the nearest 0.05 cm^3 or to 1 decimal place. Candidates should be reminded that they must indicate which titres they are using in their calculation.

(c)(i) to **(vi)**
Most candidates were aware of the basic methods and formulae involved in titration based calculations and therefore gained some credit in this section. However, many did not gain credit for giving their final answers to 3 or 4 significant figures. In **(v),** candidates were required to use the M_r they had found in **(iv)** to suggest which acid was present. Credit was given even if **(iv)** was incorrect, as long as the suggested acid followed the calculated M_r. A significant number of candidates were not able to give the test for the presence of an unsaturated compound in **(vi).**

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Question 2

Although most candidates used a sensible layout to record their results, some were confused.

(a) Candidates' results needed to include at least four mass readings, with each reading having a suitable heading and units. Units were generally given but many headings were imprecise, in that they did not specify the stage of the experiment at which the reading was taken. Some candidates also confused the mass of water lost and the mass of anhydrous solid. It was necessary to show that the mass of crucible plus contents was constant, in order to be sure that all the water of crystallisation had been lost. Most candidates gained partial credit for carrying out the heating accurately.

(b) (i) and **(ii)**
Most candidates realised that, in order to find the value of **x**, it was necessary to calculate a mole ratio. Many carried this out correctly but some did not recognise that **x** has to be an integer.

(c) (i) and (ii)
This section proved challenging to most candidates. Whilst most were familiar with errors that would have led to a value of **x** being lower than the theoretical value, this was commonly said to arise when the solid was heated insufficiently. However, in this case it was specified that the candidates had found a value that was higher than theory and only the most able candidates suggested an acceptable reason for this result.

Question 3

Candidates should be reminded that gas tests should be carried out where gases are produced and that precise language should be used when describing any observations seen. It was noticeable that the answers to **(b)** were much better than those in **(a).** This is presumably due to candidates being able to draw more directly on the Qualitative Analysis Notes for part **(b)**.

(a) (i) Few candidates noted the sublimation of the solid or the formation of white smoke. Although a number stated that the gas turned litmus blue or was ammonia, few gave both of these facts.

(ii) Many candidates successfully noted the effervescence produced, although a number did not identify the gas as being carbon dioxide.

(iii) When sodium hydroxide was added, no visible reaction occurs. Some candidates stated that such a negative result was incorrect and suggested some form of reaction, usually the formation of a precipitate.

(iv) Many candidates correctly identified the anions and cations present but did not always include observational evidence to support these conclusions. Some candidates appeared confused about which are cations and which are anions.

(v) A positive test to show the presence of NH_4^+ was needed. It was therefore insufficient to say that no precipitate was formed when aqueous sodium hydroxide or ammonia was added.

(iv) Most candidates observed a white precipitate but a significant number who had actually stated that a carbonate was present in **FA** 4 identified this precipitate as being barium sulfate.

(b) (i) and **(ii)**
This part was generally very well done. However, credit were lost by candidates who did not read, as given in the introduction, that the ions present were Al^{3+}, Ca^{2+}, Zn^{2+} and Pb^{2+}. This led to the suggestion of the presence of other ions, particularly Mg^{2+}.

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CHEMISTRY

Paper 9701/36
Advanced Practical Skills 2

Key Messages

- Instructions in the rubric need to be read and acted upon, such as recording all data specified.
- Candidates should be aware that mass and weight are not synonymous.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General Comments

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- 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.

It is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

This paper proved accessible to most candidates. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on Specific Questions

Question 1

Almost all of the candidates completed the practical work, and were able to gain credit both for accuracy and the calculation. This question was generally answered well by a large majority of candidates.

(a) Candidates should be reminded to record burette readings for the rough titration, even though these do not need to be to the same level of precision as those for the accurate titres. Most candidates supplied the balance readings and mass of **FB 1** used as well as giving correct headings and units. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 or did not have concordant titres. Concordant, in this context, means that two or more titres should be within 0.1 cm^3. Most candidates gained credit for the accuracy with which they carried out the titration.

(b) The majority of candidates calculated a suitable value of the volume of **FB 5** to be used in the calculation, with few selecting titres with a spread of more than 0.20 cm^3. Some rounded the value to the nearest 0.05 cm^3 or to 1 decimal place. Candidates should be reminded that they must indicate which titres they are using in their calculation.

(c) Most candidates were clearly aware of the formulae and methods involved in volumetric based calculations and therefore gained some credit in this section. However later parts proved more challenging with many candidates not correctly determining the mole ratio from the equation in **(iv)**

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or carrying out incorrect calculations in **(v)**. Candidates should be reminded that answers need to be quoted to 3 or 4 significant figures.

(d) Many candidates did not double the error in the single reading of a burette when calculating the maximum percentage error in the titre.

Question 2

Candidates should be encouraged to draw up results tables in advance of collecting data as this aids clear recording of the required information.

(a) Most candidates used masses of **FB 6** in the ranges specified and recorded all masses to the same number of decimal places. Candidates often confused the mass of water given off and the mass of anhydrous residue. Many candidates were awarded credit for accuracy of their results.

(b) In **(i)** it is possible to argue, with relevant reasoning, that either of the two experiments in **(a)** is more accurate and the mark scheme credited either answer. Candidates needed to take care to use the mass of water from the specified experiment in **(i)** in the answer to **(ii)**. Most achieved this and many also correctly balanced the equation in **(iv)**. Answers to **(iv)** to **(vii)** generally showed good understanding of the chemistry involved; candidates were not so confident with **(viii)**.

(c) Very few candidates gave a practical suggestion to avoid the absorption of water on cooling.

Question 3

Careful reading of the instructions is needed for the tests to be carried out correctly. It is also essential that the observations are precise and use the correct scientific terminology.

(a) Most candidates recorded that white precipitates were seen with both sodium hydroxide and aqueous ammonia in **(i)** but a significant number did not record the effect of adding excess reagent to these precipitates.

In **(ii)** both barium ions and an acid are required. Some candidates incorrectly suggested sulfuric acid for testing for the presence of a sulfate.

It was pleasing to note that a large number of correct ionic equations were seen.

(b) Accurate recording of observations was required here. If a gas is produced, the observation must be fizzing (or other suitable word). Some candidates did not notice the reaction between magnesium and **FB 8**. Many identified, and correctly justified, **FB 7** as sulfuric acid.

Parts **(iii)** and **(iv)** proved challenging with a significant number of candidates correctly quoting the colour changes but few relating these to the iodine produced and the iodide ion present in **FB 9**.

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CHEMISTRY

Paper 9701/41
A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly key definitions.
- Candidates should set out calculations which clearly explain what the numbers refer to and ensure that all answers are legible.
- Candidates should ensure that they have read questions carefully before answering them. For example, it was evident that this had not happened in **Question 1(a)** where the correct electron codes were not always used.

General Comments

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

The answers to the questions in **Section B** were generally of a higher standard than previously.

The arithmetical working in calculation questions should be set out clearly, to allow Examiners to award credit for 'error-carried-forward' wherever possible.

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

Comments on Specific Questions

Section A

Question 1

(a) The 'dot-and-cross' diagram of NH_4Cl caused many problems. The dative bond needed to be shown with two identical nitrogen electrons (oo) within it and the chloride ion needed to have four electron pairs shown around it with one of these pairs containing a Cl electron and an H electron.

(b) (i) Most candidates gave the correct answer here.

(ii) This equation was given correctly by many candidates. A common error was including H_2 as an additional product.

(iii) This proved difficult for many candidates. Some candidates did not relate their answer to the water absorbing properties of CaO and MgO; 'CaO is a better drying agent' needed further clarification for credit to be awarded.

(c) (i) Most candidates gained credit for the equation, although some did not balance the equation for the oxygen.

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(ii) Both the trend and its explanation in terms of cation size and polarisation of the anion were well understood by candidates. Some, however, wrote in terms of atomic, rather than cationic, size, and did not specify which ion was undergoing polarisation.

Question 2

(a)(i)(ii) This proved difficult for many candidates. The key points here were that the C-C bond was a stronger covalent bond than the Si-Si bond and that the metallic bond in tin was weaker than the covalent bond in germanium.

(b) Only a few candidates were awarded full credit here. Answers sometimes revealed insufficient knowledge of the reactions of Group IV compounds; **(b)(i)** was most commonly correctly answered but the other parts tended to have unbalanced equations.

Question 3

(a)(i)(ii) This was generally poorly answered. Most candidates knew that a Brønsted-Lowry acid is a proton donor and a Brønsted-Lowry base is a proton acceptor. However they could not apply this theory to construct an equation of the acid, HZ, or base, B^-, with NH_3 and CH_3OH.

(b) (i) Almost all candidates gave the correct answer here.

(ii) This was answered well by candidates. The most common error was the omission of 'rate'.

(c) (i) Many gave the correct definition for a buffer.

(ii) This proved a trickier question with only the more able candidates explaining how the buffer works in terms of HZ and Z^-. A number of explanations were quite general. Examiners expected a le Chatelier's principle type of argument.

(d) (i) Most candidates gained some credit for this calculation but not as many as in previous series.

(ii) Almost all gave the correct answer here.

(iii) Candidates struggled to correctly extract and use the data in this question.

(iv) A pleasing number of candidates correctly calculated the pH of the buffer solution; a significant number as credit for error carried forward from **(iii).**

(e) Many candidates gained some credit here, though $CH_3CH_2CO_2Cl$ was a common error for **G**, as well as HCl for **H**.

Question 4

(a) Only a few candidates were awarded credit for this question as many did not know the correct definition of bond energy.

(b) (i) By contrast, the bond energy trend and the explanation were well described, with most candidates stating that the decrease in bond energies was due to the increasing bond length.

(ii) Many candidates were able to give a correct answer here.

(c) Most candidates gained credit for the extraction of the relevant data from the *Data Booklet*. Stronger candidates went on to describe the breakdown of CFCs to release chlorine radicals, although the majority of candidates did not state that ozone was broken down into molecular oxygen.

(d) This proved a trickier question with only the more able candidates suggesting a correct structure for all three products. The most common error in reaction 1 was the acyl chloride rather than the

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chlorinated propanoic acid, in reaction 2 was the iodine product rather than the chlorine product and in reaction 3 was exchanging the incorrect bromine for a hydroxyl group.

(e) (i) Almost all gave the correct answer here.

(ii) Most candidates gave the correct type of reaction.

(iii) This was well answered by candidates**.** The most common errors were including the bond energy of C*l*–C*l* for the C*l* radical, and reversing the sign of the final answer.

(iv) As in **(iii)**, using the bond energy of I-I was an error often seen here.

(v) Many candidates correctly suggested that the reaction with iodine is endothermic. The most common error was suggesting that the activation energy is too high.

(vi) Most candidates gained some credit here, although there were quite a few unbalanced equations. Other common errors included the omission of the 'dot' indicating the presence of a radical species and incorrect radical species.

Question 5

(a) Polymerisation was well known in general. The key idea in **(i)** was that many monomers join together to form a polymer; an explanation in terms of addition or condensation polymerisation was credited. In **(ii)** quite a number of candidates suggested condensation instead of addition. Only the more able candidates correctly described the changes in chemical bonding that occur during polymerisation in **(iii)**. Most candidates stated that the C=C bond would break but omitted that new C-C bonds would be formed between the monomers.

(b) Many candidates found naming propenoic acid difficult.

(c) (i) Most candidates gained some credit here. A common error was a repeat unit with the free di-acid instead of the carboxylate salt.

(ii) This part caused problems for many candidates who were unable to state the bond angle change from 120° to 109.5°. A common error was stating the change from 120° to 90°. Accepted suggestions for the explanation varied from recognising that the carbon changes from being sp^2 to sp^3 to stating that the geometry around the carbon changes from being trigonal planar to tetrahedral.

(d) (i) This question was not answered well. Many candidates did not realise that a diagram involving water hydrogen-bonded to the polymer needed to be drawn. Common errors were not including the lone pair on oxygen or the δ+ and δ- charges and hydrogen bonding the water to the C-H group of the polymer.

(ii) This proved to be a tricky question with only the more able candidates suggesting a correct answer. Accepted suggestions varied from the solution becomes darker in colour as the polymer absorbs water, to the solution becoming paler as the Cu^{2+} swaps with Na^+ ions.

(e) (i) Almost all candidates gained some credit here. The most common errors were identifying the functional groups as peptide and amine.

(ii) Many candidates correctly identified ammonia here. Ammonium chloride was a common error.

(iii) Most candidates identified the correct other product here.

(iv) Only the more able candidates identified the correct reagents and conditions. Some omitted 'heat' or 'aqueous' with their acid.

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Section B

Question 6

(a) (i) Many candidates were awarded credit for a correct answer here.

(ii) Many candidates drew a tripeptide with two displayed peptide bonds, but did not have the amino acids in the correct sequence. Another quite common error was including an oxygen atom in the peptide bond, thus -CHR-CO-O-NH-CHR-.

(iii) Many candidates gave the correct response here.

(iv) Most candidates scored at least partial credit here. The term "hydrophobic interaction" was not awarded credit as this is not a correct chemistry term. A common error was stating covalent or peptide for the bond type, rather than hydrogen bond or van der Waals'.

(b) (i) This was well answered by candidates showing knowledge of competitive and non-competitive inhibitors. A few candidates incorrectly suggested that the inhibitor bonded to the substrate.

(ii) Almost all candidates drew a correct curve here.

Question 7

(a) Many candidates drew clear labelled diagrams. Common errors were the omission of the buffer or electrolyte solution or a suitable material to place the amino acid mixture on.

(b) Most candidates gained at least partial credit here. Mass and charge of amino acid species were the most common answers. A common error was voltage.

(c) Many candidates' definitions were too imprecise to be awarded credit here. Key words looked for but not often seen were **ratio** and **concentration**. As is often the case in such a definition, the use of an equation (e.g. K = (X)a/(X)b) would have helped.

(d) The calculations often showed that the principle of solvent extraction was not well understood. Only the more able candidates gained full credit, but credit for error-carried-forward could be awarded if the working was shown clearly.

Question 8

(a) (i) This question was answered fairly well with candidates understanding that nitrates are soluble.

(ii) This question was not answered well. Only the ions, Ba^{2+}, Pb^{2+} and SO_4^{2-}, were credited. Many candidates gave incorrect ions which contradicted any correct ions stated. Some candidates correctly stated that $BaCO_3$/$PbCO_3$/$CaSO_4$ would be formed but did not mention that they are insoluble in water.

(b) (i)(ii) Most candidates gained some credit here, usually by stating fertilisers. A common error seen was pesticides.

(iii) This was answered well by most candidates.

(c) (i) Only the more able candidates gained credit for the equations here, with a common error being unbalanced equations.

(ii) Only a few candidates scored credit here. A common error was the stating the Contact process.

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CHEMISTRY

Paper 9701/42
A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with balancing both molecular and ionic equations.
- Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly key definitions.
- Candidates should set out calculations which clearly explain what the numbers refer to and ensure that all answers are legible.
- Candidates should ensure that they have read questions carefully before answering them. For example, it was evident that this had not happened in **Question 1(a)** where the correct electron codes were not always used.

General Comments

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

The answers to the questions in **Section B** were generally of a higher standard than previously.

The arithmetical working in calculation questions should be set out clearly, to allow Examiners to award credit for 'error-carried-forward' wherever possible.

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

Comments on Specific Questions

Section A

Question 1

(a) The 'dot-and-cross' diagram of NH_4Cl caused many problems. The dative bond needed to be shown with two identical nitrogen electrons (oo) within it and the chloride ion needed to have four electron pairs shown around it with one of these pairs containing a Cl electron and an H electron.

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(ii) This equation was given correctly by many candidates. A common error was including H_2 as an additional product.

(iii) This proved difficult for many candidates. Some candidates did not relate their answer to the water absorbing properties of CaO and MgO; 'CaO is a better drying agent' needed further clarification for credit to be awarded.

(c) (i) Most candidates gained credit for the equation, although some did not balance the equation for the oxygen.

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(ii) Both the trend and its explanation in terms of cation size and polarisation of the anion were well understood by candidates. Some, however, wrote in terms of atomic, rather than cationic, size, and did not specify which ion was undergoing polarisation.

Question 2

(a)(i)(ii) This proved difficult for many candidates. The key points here were that the C-C bond was a stronger covalent bond than the Si-Si bond and that the metallic bond in tin was weaker than the covalent bond in germanium.

(b) Only a few candidates were awarded full credit here. Answers sometimes revealed insufficient knowledge of the reactions of Group IV compounds; **(b)(i)** was most commonly correctly answered but the other parts tended to have unbalanced equations.

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(a)(i)(ii) This was generally poorly answered. Most candidates knew that a Brønsted-Lowry acid is a proton donor and a Brønsted-Lowry base is a proton acceptor. However they could not apply this theory to construct an equation of the acid, HZ, or base, B^-, with NH_3 and CH_3OH.

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(iv) As in **(iii)**, using the bond energy of I-I was an error often seen here.

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Section B

Question 6

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(iv) Most candidates scored at least partial credit here. The term "hydrophobic interaction" was not awarded credit as this is not a correct chemistry term. A common error was stating covalent or peptide for the bond type, rather than hydrogen bond or van der Waals'.

(b) (i) This was well answered by candidates showing knowledge of competitive and non-competitive inhibitors. A few candidates incorrectly suggested that the inhibitor bonded to the substrate.

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(b) Most candidates gained at least partial credit here. Mass and charge of amino acid species were the most common answers. A common error was voltage.

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(iii) This was answered well by most candidates.

(c) (i) Only the more able candidates gained credit for the equations here, with a common error being unbalanced equations.

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CHEMISTRY

Paper 9701/43
A2 Structured Questions

Key Messages

Candidates should ensure that they have read questions carefully before answering them. It was evident that this had not happened in **Question 1(c)** where ionic equations were often not seen as requested and in **Question 6(f)(i)** where structural rather than stereoisomerism was often defined.

Candidates should be reminded of the need to re-visit and revise AS material while preparing for the A Level examination.

General Comments

There was no general evidence of candidates running out of time. The answers to **Section B** were generally of a high standard, and overall the neatness and legibility of answers was good.

The general standard of answers was good. Most candidates thought carefully about their answers before putting pen to paper, and the layout of calculations was usually very clear.

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

Comments on Specific Questions

Section A

Question 1

(a) Only the more able candidates gained full credit for this electron structure. Errors included not showing a dative bond, not including the **one** additional electron to form the negative charge, including bonds with three electrons rather than two or four, not showing each atom surrounded by eight electrons and not showing a total of 24 electrons in the ion.

(b) (i) Most candidates gave a correct equation here, although there were quite a few that were unbalanced, showing O_2, rather than ½ O_2, on the right hand side.

(ii) The trend and the explanation were generally well described.

(c) It was expected that candidates would know that the brown gas was NO_2, so answers involving the production of HNO_2 were not awarded credit. Most candidates attempted an ionic equation, though not all were correctly balanced. Some equations involving NO or Cu^+ were seen, and these were awarded partial credit.

Question 2

(a) The assumptions of the kinetic theory of gases were well-known in general. However, many candidates could not give them with sufficient detail for full credit to be awarded.

(b) (i) Quite a number of candidates suggested 0 K for the temperature, or 1 atm for the pressure, rather than the general “low temperature and high pressure”.

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(ii) This part was generally well answered, in terms of the intermolecular forces or the sizes of molecule being more significant under conditions of low temperature and high pressure.

(c)(i) The explanation required for the statement that the reaction was endothermic was either in terms of le Chatelier's principle (as heat is supplied, the equilibrium moves to the right hand side) or in terms of bond breaking requiring an input of (heat) energy.

(ii) Most candidates answered well here, choosing the halogenation of arenes, using either Cl_2 or Br_2. The most common errors were to describe the halogenation of phenol or the addition to alkenes, neither of which requires $AlCl_3$ as catalyst.

Question 3

(a) Most candidates were unable to give correct equations here. Candidates seemed to struggle with converting the definition of bond energy (i.e. the energy required to completely break one mole of bonds in the gas phase) into a chemical example.

(b)(i) By contrast, the bond energy trend and the explanation were well described, with most candidates stating that the decrease in bond energies was due to the increasing bond length causing less effective orbital overlap.

(ii) Accepted suggestions varied from recognising that the fluorine atom is very electronegative, so does not readily share its electrons, to appreciating that there would be repulsion between the lone pairs on the two fluorine atoms (or repulsion between the two nuclei), due to the shortness of the F-F bond. The first of these was the most common way in which candidates gained credit.

(c)(i) These calculations were carried out effectively, with most candidates gaining full credit. Errors included calculating the two ΔH values as positive rather than negative quantities, or not multiplying the H-X bond energy by two.

(ii) The trend was well known, but the explanations offered did not always make it clear that it was the H-X bond energy that decreased (rather than the X-X bond energy).

(d)(i) This calculation was well done by the vast majority of candidates.

(ii) Only a few gained full credit for this equation, despite the fact that many would have known the analogous equation with chlorine. Some candidates gave the correct species but did not balance their equation.

Question 4

(a) A minority of candidates gained full credit here. The key to **(i)** was to appreciate that some of the electrons in graphite are delocalised, whereas those in silicon are localised in the covalent bonds of the macromolecular structure. A similar argument contrasts the metallic bonding in tin (delocalised electrons) with the more localised electrons in germanium.

(b) Many answers revealed gaps in candidates' knowledge of the reactions of Group IV compounds. In **(i)** the most common error (apart from not balancing the equation by writing O_2 rather than ½ O_2) was to produce Pb metal. In **(ii)** $PbCl_2$ was seen as the product in the absence of Cl_2 (i.e. $2PbO_2 + 4HCl \longrightarrow 2PbCl_2 + 2H_2O + O_2$). Part **(iii)** produced equations including Na_2O and $Sn(OH)_2$ as products. Most candidates gained credit for a correct equation in **(iv)**

Question 5

(a) Candidates generally made a good attempt at this question. The most common error in the products was suggesting that the bromination of phenol produced only mono-bromophenol, rather than the tri-bromo derivative. The reaction conditions required (aq) to be specified in **(i)** and light (or heat) in **(iii)**, in the absence of water. No catalyst such as $AlCl_3$ was required in any of the three reactions. The most common errors in the balancing of the equations were to omit the 3HBr from

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the right hand side in **(i)** and the HBr in **(iii)**. Candidates seemed to have forgotten that both reactions **(i)** and **(iii)** substitute a bromine atom for a hydrogen atom already on the ring, despite naming them correctly as "electrophilic substitution" and "free radical substitution" reactions.

(b) This question was generally well answered. The answers in **(ii)** were marked consequentially on the compounds the candidate suggested in **(i)**. Two common errors were not identifying cyclohexanone as a product and incorrectly stating that ethanoic acid or cyclohexanone give positive iodoform tests.

Question 6

(a) Almost all candidates gained credit for the correct definition of a Brønsted-Lowry acid, although some candidates seemed to confuse it with the definition of a Lewis acid, which is not on the syllabus.

(b) (i) Most candidates gained at least partial credit for showing the hydrogen bonding here. Common errors were not including either the lone pair on oxygen (or nitrogen), or the δ+ and δ- charges. Some candidates drew the water molecule as O-H-O rather than H-O-H, whilst others did not read the question carefully enough, and showed hydrogen bonding between a $-CO_2H$ and an $-NH_2$ group, rather than to water molecules.

(ii) Most candidates gained credit here, though some candidates drew the zwitterion as $HN^+CH_2CO_2^-$ rather than $H_3N^+CH_2CO_2^-$.

(c) Many candidates were not sure of this mechanism. Credit was available for showing the δ+ and δ- in the C-C*l* bond, drawing a curly arrow from the lone pair of electrons on the nitrogen atom to the δ+ carbon, and a curly arrow breaking the C-C*l* bond to give C*l*⁻. Either the S_N1 or the S_N2 mechanism was accepted. In either case the intermediate carbocation or 5-coordinated transition state was required.

(d) Where candidates were careful to specify the correct charged species in each case, they were awarded full credit. Apart from confusing the alkaline and acidic solution (such that aspartic acid at pH 14 was shown as $HO_2CCH_2CH(NH_3^+)CO_2H$), the most common errors were drawing the mono-cation or mono-anion rather than the doubly-charged species.

(e) (i) Many candidates were awarded credit for a correct answer here.

(ii) A number of candidates thought a dipeptide contained two peptide bonds rather than one, and so drew structures of a tripeptide containing three amino acid units. Another quite common error was including an oxygen atom in the peptide bond, thus -CHR-CO-O-NH-CHR-.

(f) (i) This question was not very well answered. Most candidates incorrectly quoted the definition of *structural* isomerism rather than *stereoisomerism*.

(ii) Only a few candidates were able to correctly identify that **J** was identical to **F**. Twisting the right hand of structure **J** through a 60° clockwise turn (as seem from the right hand side) produces structure **F**. Structure **G** (the most common answer) and structure **H** both have the opposite chirality to **F** at the left hand carbon atom.

(iii) The fourth optical isomer had the same chirality as **F** (and **J**) at the left hand carbon, but the opposite chirality at the right hand carbon:

Section B

Question 7

(a) This was well answered by most candidates. Common choices for a non-competitive inhibitor in **(i)** were heavy metals such as silver, mercury, lead or cadmium (or their ions), although some chose penicillin or organophosphate "nerve gas" compounds, both of which were accepted. Candidates answered **(ii)** well, many mentioning the bonding of the inhibitor to an allosteric site, with the consequent change of shape in the active site not allowing the substrate to bond and undergo

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reaction. The curve in **(iii)** needed to start at the origin, with a lower gradient than the original, but to join the original curve at the same maximum value.

(b) (i) Most candidates knew the correct order here, starting with mRNA and finishing with tRNA.

(ii) Most candidates either knew that UGA is a 'stop' codon, or guessed that it coded for either 'stop' or 'start'. Either gained credit.

(c)(i) Knowledge of the breakdown products (ADP + inorganic phosphate) was widespread.

(ii) Accepted uses included muscle contraction; active transport; synthesis of new compounds; reproduction of DNA; production of electric charge in nerve cells; and bioluminescence.

Question 8

(a) Many candidates incorrectly suggested X-ray crystallography, thinking that X-rays had a longer wavelength than the radio waves used in NMR spectroscopy.

(b) While most candidates correctly stated that hydrogen atoms are associated with too few electrons to diffract X-rays, only a minority were able to explain that NMR uses the energy difference between the two spin states of protons in an external magnetic field to differentiate between protons in different chemical environments.

(c) Most candidates were able to deduce that the larger number of electrons in the sulfur atom would allow this to produce the strongest reflection. Some candidates incorrectly ascribed this to the higher atomic mass, or higher proton number, of sulfur.

(d) This question relied on candidates making deductions from both the mass spectrum of compound **P**, and the NMR spectra of compounds **P** and **Q**. After having successfully carried out the calculation in **(i)** to deduce that **P** contained three carbon atoms per molecule, a number of candidates did not make use of this fact in their answers to **(iv)**.

(ii) Most correctly deduced that the broad singlet at δ 4.5 was the OH peak.

(iii) Most also recognised that **Q** contained protons in three different environments.

(iv) Candidates could approach this question in three different ways, and all three were seen by Examiners.

- Examination of the spectrum of **Q** shows a peak at δ 11.8, in the $-CO_2H$ region according to the *Data Booklet*. A carboxylic acid can only be obtained from a primary alcohol.
- The spectrum of **P** contains 4 peaks; that of the secondary alcohol *with three carbon atoms*, $(CH_3)_2CHOH$, would only contain 3 peaks, as the two CH_3 groups are in identical environments.
- The peak at δ 3.5 in the spectrum of **P** must arise from protons attached to the same carbon as the OH group (*Data Booklet* range 3.3 – 4.0). This peak is a *triplet*, so the adjacent carbon atom must have *two* hydrogens attached to it. This is true for $CH_3CH_2CH_2OH$ but not for $(CH_3)_2CHOH$.

Candidates need more practice in interpreting NMR splitting patterns: a number of them incorrectly interpreted a triplet of peaks as arising from the three Hs in a CH_3 group, rather than from one (or more) Hs on a carbon atom adjacent to a CH_2 group.

(v) Although most candidates correctly identified **Q** as propanoic acid, some suggested propanal, despite the *Data Booklet* giving the –CHO range as only stretching from δ 9.0 – 10.0.

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Question 9

(a) Most candidates correctly identified the two allotropes as graphite and diamond in **(i)**, although some suggested carbon nanotubes and graphene, and even Kevlar and spider silk. The differences looked for in **(ii)** were those of the *properties* of diamond and graphite, rather than their structures: colour; hardness; **electrical** conductivity (diamond is a good **thermal** conductor); density; and **melting** point (their boiling points are the same, as the different 3-dimensional structures have both been destroyed in the liquid state). *Comparisons* needed to be made between the two allotropes: i.e. 'diamond has a high melting point' needed further clarification because so does graphite, but its melting point is (only) 23 ^{o}C lower than that of diamond.

(b) The key point here was that buckminsterfullerene is an *unsaturated* molecule, with sp^2 carbon atoms joined by (partial) double bonds to only three other atoms. It could form $C_{60}H_{60}$ without breaking any C-C single bonds.

(c) The calculations in **(i)** and **(ii)** were successfully carried out by most candidates.

(iii) Most candidates correctly predicted that graphene would be an electrical conductor, due to its *extended* delocalisation of electrons. Only a small number appreciated that although the individual molecules of buckminsterfullerene contain delocalised electrons, these do not extend through the bulk of the material, and so, like benzene, the substance would be an electrical insulator.

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Paper 9701/51

Planning, Analysis and Evaluation

Key Messages

Candidates must make sure that they read questions carefully before attempting to provide a response. In particular, they should be aware that guidance on the points to be covered in their answers always indicates where credit is likely to be awarded.

Where an experiment is being described it is best to describe each step in a separate paragraph. This would help to avoid essential details being missed out.

Any explanation of the precautions to be taken when performing an experiment should clearly relate to the procedure being carried out.

General Comments

Question 1 proved to be the more difficult of the two questions. It was not expected that candidates would have carried out an experiment to measure the change in temperature when a solid dissolves but they should have possessed sufficient experience of enthalpy experiments to apply that knowledge to this situation. It appeared however that they were uncertain in their application of Le Chatelier's principle and as a result lost confidence in tackling the questions asked. It is vital for this paper that, even if opportunities for practical experience are limited by lack of apparatus, sufficient class time is devoted to discussing what would be involved in experiments related to syllabus topics. Students should be given sufficient practice at devising plans for a wide variety of experiments.

Question 2 was well answered where candidates had taken care to generate reliable data in **(a)**. The scales for the axes were usually sensibly chosen and the quality of the plotting of points was an improvement on previous sessions. However it is worth a reminder that the points themselves should be indicated clearly with a well-sharpened pencil. Examiners will not give the benefit of doubt to thick lines whose exact position cannot be easily identified. In **(e)**, some work on the determination of percentage errors needs to be done: the question was frequently left blank or answers were given that showed candidates had no concept of the likely effect on an answer of a relatively small error in a measurement taken.

Comments on Specific Questions

Question 1

(a) (i) Although a majority correctly recognised that the temperature of the water would decrease, only the most able could provide an explanation in terms of the lattice energy and hydration enthalpy. Because both enthalpies are negative, it does make an answer difficult to word correctly and great care is needed in the use of the words 'greater' or 'smaller'. It is best in these situations to give an appropriate equation relating these quantities to the enthalpy of solution, (enthalpy of solution = enthalpy of hydration of ions – lattice energy) and use this to provide an explanation. A surprising number of candidates seemed to think that lattice energies and hydration energies varied with concentration.

(ii) Candidates could gain credit by plotting concentration against either temperature or temperature change but a significant minority confused the two types of graph so that graphs showing the temperature change decreasing with increased concentration were not uncommon. Another frequent error was to not start the graphs on one of the axes. If a mistake had been made in **(a)(i)** it was still possible to gain credit in this part if the graph drawn matched the prediction that was made.

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(b) The identification of the independent and the dependent variable was generally well done and only a small number of errors were seen. The Examiners however were looking for 'temperature change' and not just 'temperature' when stating the dependent variable.

(c) The question indicated that candidates should 'label each piece of the apparatus used, indicating its size or capacity and both the temperature range and precision of the thermometer'. Many candidates did not do this and could not be awarded credit. Most candidates positioned the thermometer correctly but fewer indicated the size of the container in which the thermometer was placed. It was expected that the experiment would either be done in a polystyrene cup or in a beaker that was suitably lagged. In either case a lid was expected.

(d) In this part, credit was available for answering the guidance points labelled **(i)** to **(iv)**. Most suggested a reasonable number of different experiments to do and a large majority measured the temperature at the start followed by the lowest temperature reached. However it did not answer the question correctly if a candidate simply put 'the temperature change was noted' and it is incorrect to suggest leaving the solution for a specified period of time before reading the thermometer. The volume of water was sometimes not mentioned at all and many did not attempt the calculation required in the last part. The mass of ammonium nitrate should have been twice the volume of water used.

Quite a few candidates confused this experiment with an experiment to determine the solubility of ammonium nitrate at various different temperatures. Some credit could still be obtained but it was an unfortunate error to make.

(e) To obtain credit, candidates had to give a hazard and the precaution that they would then take within the context of the experiment they were describing. Since no organic matter or combustible material was involved in carrying out the procedure, a precaution based on this was not accepted as a response. Either taking care not to grind the ammonium nitrate or disposing of it only after it had been diluted to less than 0.5 mol dm^{-3} were the accepted answers. Despite the information given in **(c)** this question proved to be very difficult for many candidates.

(f) Most candidates gained at least partial credit here. Even where an incorrect experiment had been described in **(c)** and **(d)** it was still possible to provide measurements that were accepted by the Examiners. Care needed to be taken to provide correct units for the quantities mentioned.

Question 2

(a) Candidates were required to provide an appropriate heading (solubility), its units (g/100g) and the correct formula used to calculate the numerical data. Although some remembered all three points many did not include one of them. Credit was also available for quoting the figures to two decimal places and for providing the correct data. A common error seen was not giving the concentration in g/100g although this error on its own did not hinder candidates from obtaining credit in the remaining parts of the question.

(b) Credit for the correct labelling of the axes and for plotting points was awarded based on the data calculated by candidates in **(a)** even where these were incorrect. The plotting was well done and Examiners noted a higher degree of accuracy than has often been the case in the past. Two curves were required to show how the solubility of the sodium sulfate varied with temperature. Some were tempted to draw two straight lines despite the statement in the introduction to the question. Since candidates would be unfamiliar with the best way to join the points, a range of different pairs of curves were accepted as long as they provided a point of intersection. The curves (particularly the left-hand one) were difficult to draw freehand and the Examiners allowed a fair amount of 'freehand wobble'.

(c) To allow for candidates whose positioning of the curves was incorrect and for those who had drawn straight lines, credit was awarded for correctly reading the temperature and the solubility where the candidate's lines intersected. Credit was also obtainable for those who had drawn a single continuous line through all the points so long as the value was read at a maximum turning point on the curve. Although the values at the point were usually quoted correctly, several candidates forgot to provide units.

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(d) Candidates found this part difficult and many did not notice that the question asked for a cross to be placed on the graph to represent the new point that would have been obtained if the temperature had been read inaccurately. The introduction referred to the error being made for the 4th experiment but many who did mark a cross on their graph ignored this. A common mistake was to place the cross either vertically above or below the original 4th point and only a few correctly placed the cross horizontally to the right. Those who did, often struggled to provide the correct explanation that this would give an apparent increase in the transition temperature.

(e) The calculation of the new solubility was based on the data the candidate had obtained in **(a)** even where this was erroneous. This meant that many were able to gain some credit but converting this to a percentage error difference caused some difficulty; a common error being to divide the difference in the two solubilities by the new solubility instead of the original. Others did not multiply by 100 to quote the error as a percentage. A significant number left this part unanswered and the Examiners had the impression that some had not encountered a calculation of this sort before.

(f) This question was answered well by candidates who had calculated the correct data but it was clearly very difficult for those whose solubilities did not suggest a clear trend.

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Paper 9701/52

Planning, Analysis and Evaluation

Key Messages

Candidates must make sure that they read questions carefully before attempting to provide a response. In particular, they should be aware that guidance on the points to be covered in their answers always indicates where credit is likely to be awarded.

Where an experiment is being described it is best to describe each step in a separate paragraph. This would help to avoid essential details being missed out.

Any explanation of the precautions to be taken when performing an experiment should clearly relate to the procedure being carried out.

General Comments

Question 1 proved to be the more difficult of the two questions. It was not expected that candidates would have carried out an experiment to measure the change in temperature when a solid dissolves but they should have possessed sufficient experience of enthalpy experiments to apply that knowledge to this situation. It appeared however that they were uncertain in their application of Le Chatelier's principle and as a result lost confidence in tackling the questions asked. It is vital for this paper that, even if opportunities for practical experience are limited by lack of apparatus, sufficient class time is devoted to discussing what would be involved in experiments related to syllabus topics. Students should be given sufficient practice at devising plans for a wide variety of experiments.

Question 2 was well answered where candidates had taken care to generate reliable data in **(a)**. The scales for the axes were usually sensibly chosen and the quality of the plotting of points was an improvement on previous sessions. However it is worth a reminder that the points themselves should be indicated clearly with a well-sharpened pencil. Examiners will not give the benefit of doubt to thick lines whose exact position cannot be easily identified. In **(e)**, some work on the determination of percentage errors needs to be done: the question was frequently left blank or answers were given that showed candidates had no concept of the likely effect on an answer of a relatively small error in a measurement taken.

Comments on Specific Questions

Question 1

(a) (i) Although a majority correctly recognised that the temperature of the water would decrease, only the most able could provide an explanation in terms of the lattice energy and hydration enthalpy. Because both enthalpies are negative, it does make an answer difficult to word correctly and great care is needed in the use of the words 'greater' or 'smaller'. It is best in these situations to give an appropriate equation relating these quantities to the enthalpy of solution, (enthalpy of solution = enthalpy of hydration of ions – lattice energy) and use this to provide an explanation. A surprising number of candidates seemed to think that lattice energies and hydration energies varied with concentration.

(ii) Candidates could gain credit by plotting concentration against either temperature or temperature change but a significant minority confused the two types of graph so that graphs showing the temperature change decreasing with increased concentration were not uncommon. Another frequent error was to not start the graphs on one of the axes. If a mistake had been made in **(a)(i)** it was still possible to gain credit in this part if the graph drawn matched the prediction that was made.

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(b) The identification of the independent and the dependent variable was generally well done and only a small number of errors were seen. The Examiners however were looking for 'temperature change' and not just 'temperature' when stating the dependent variable.

(c) The question indicated that candidates should 'label each piece of the apparatus used, indicating its size or capacity and both the temperature range and precision of the thermometer'. Many candidates did not do this and could not be awarded credit. Most candidates positioned the thermometer correctly but fewer indicated the size of the container in which the thermometer was placed. It was expected that the experiment would either be done in a polystyrene cup or in a beaker that was suitably lagged. In either case a lid was expected.

(d) In this part, credit was available for answering the guidance points labelled **(i)** to **(iv)**. Most suggested a reasonable number of different experiments to do and a large majority measured the temperature at the start followed by the lowest temperature reached. However it did not answer the question correctly if a candidate simply put 'the temperature change was noted' and it is incorrect to suggest leaving the solution for a specified period of time before reading the thermometer. The volume of water was sometimes not mentioned at all and many did not attempt the calculation required in the last part. The mass of ammonium nitrate should have been twice the volume of water used.

Quite a few candidates confused this experiment with an experiment to determine the solubility of ammonium nitrate at various different temperatures. Some credit could still be obtained but it was an unfortunate error to make.

(e) To obtain credit, candidates had to give a hazard and the precaution that they would then take within the context of the experiment they were describing. Since no organic matter or combustible material was involved in carrying out the procedure, a precaution based on this was not accepted as a response. Either taking care not to grind the ammonium nitrate or disposing of it only after it had been diluted to less than 0.5 mol dm^{-3} were the accepted answers. Despite the information given in **(c)** this question proved to be very difficult for many candidates.

(f) Most candidates gained at least partial credit here. Even where an incorrect experiment had been described in **(c)** and **(d)** it was still possible to provide measurements that were accepted by the Examiners. Care needed to be taken to provide correct units for the quantities mentioned.

Question 2

(a) Candidates were required to provide an appropriate heading (solubility), its units (g/100g) and the correct formula used to calculate the numerical data. Although some remembered all three points many did not include one of them. Credit was also available for quoting the figures to two decimal places and for providing the correct data. A common error seen was not giving the concentration in g/100g although this error on its own did not hinder candidates from obtaining credit in the remaining parts of the question.

(b) Credit for the correct labelling of the axes and for plotting points was awarded based on the data calculated by candidates in **(a)** even where these were incorrect. The plotting was well done and Examiners noted a higher degree of accuracy than has often been the case in the past. Two curves were required to show how the solubility of the sodium sulfate varied with temperature. Some were tempted to draw two straight lines despite the statement in the introduction to the question. Since candidates would be unfamiliar with the best way to join the points, a range of different pairs of curves were accepted as long as they provided a point of intersection. The curves (particularly the left-hand one) were difficult to draw freehand and the Examiners allowed a fair amount of 'freehand wobble'.

(c) To allow for candidates whose positioning of the curves was incorrect and for those who had drawn straight lines, credit was awarded for correctly reading the temperature and the solubility where the candidate's lines intersected. Credit was also obtainable for those who had drawn a single continuous line through all the points so long as the value was read at a maximum turning point on the curve. Although the values at the point were usually quoted correctly, several candidates forgot to provide units.

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(d) Candidates found this part difficult and many did not notice that the question asked for a cross to be placed on the graph to represent the new point that would have been obtained if the temperature had been read inaccurately. The introduction referred to the error being made for the 4th experiment but many who did mark a cross on their graph ignored this. A common mistake was to place the cross either vertically above or below the original 4th point and only a few correctly placed the cross horizontally to the right. Those who did, often struggled to provide the correct explanation that this would give an apparent increase in the transition temperature.

(e) The calculation of the new solubility was based on the data the candidate had obtained in **(a)** even where this was erroneous. This meant that many were able to gain some credit but converting this to a percentage error difference caused some difficulty; a common error being to divide the difference in the two solubilities by the new solubility instead of the original. Others did not multiply by 100 to quote the error as a percentage. A significant number left this part unanswered and the Examiners had the impression that some had not encountered a calculation of this sort before.

(f) This question was answered well by candidates who had calculated the correct data but it was clearly very difficult for those whose solubilities did not suggest a clear trend.

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CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key Messages

- The paper successfully identified those candidates with high level practical and organisational skills.

General Comments

In **Question 1**, the prediction required knowledge of Le Chatelier's principle, which was clearly well understood, although its implications were sometimes less well explained. In **Question 2** the simplification of the description to a diagram, calculation and measurement benefitted the candidates who followed the three directed points.

For science papers, candidates may like to consider switching their calculators to the decimal setting rather than the fraction option.

Comments on Specific Questions

Question 1

(a) (i) The intent of this question was to apply Le Chatelier's Principle to an exothermic solution. The majority of candidates correctly deduced that a temperature increase would decrease solubility by promoting the endothermic (backwards) reaction.

(ii) The requirement of the sketch graph was to graphically illustrate the prediction made earlier. Some candidates labelled the solubility axis as concentration or ΔH instead of solubility. The correct prediction of a straight line or curve of negative gradient, with no plateau was given by many candidates. Some had lines with a maximum or a plateau. If candidates gave increasing in **(i)** then the inverse was accepted as an error carried forward. A correct explanation was less often seen. The line needed to show solubility at 0°C and 100°C, so it had to be drawn between these two points. There had to be some indication of the solubility at 25°C, by way of numbers on both axes. This was often not done, or 25 was given on the temperature axis but no 19 on the solubility axis. Many candidates did not assign a unit to each axis, which was a requirement for the second mark.

(b) (i) and (ii)
Most candidates identified the independent and dependent variables correctly.

Question 2

(a) The quality of diagrams was quite good. The implication of the first bullet point was that the two chemicals were to be mixed with no loss of oxygen. This required both chemicals to be in the same sealed reaction vessel but separated. This could be achieved by, for example, having one chemical in a test-tube resting in the reaction vessel. Most candidates had a reasonable set-up but did not gain the second mark, since their reagents were not separated. Some sought to introduce the hydrogen peroxide by way of a thistle funnel or dropping funnel but without a comment about the displacement of air that would happen and change the results. Although the question provided a 100 cm^3 syringe, a few candidates had collection over water into a measuring cylinder which was acceptable provided its volume was 100 cm^3. Some candidates did not label both chemicals.

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A minority of candidates managed all three steps in the calculation of the volume of hydrogen peroxide. Many others did not attempt this calculation. Some who correctly calculated it (calculator value 27.7777773) erroneously truncated it to 27 cm^3 as their answer. A number of candidates did not apply the stoichiometric ratio and others did not start with 100 cm^3 of oxygen, so neither could calculate the maximum volume of hydrogen peroxide. The reverse calculation starting from a specific volume of hydrogen peroxide was acceptable but it would only gain full credit if it produced 100 cm^3 of oxygen.

Most candidates realised that the necessary measurements were of time and volume but few structured their answers. For example, timing to the end of the reaction or timing the production of 50 cm^3 of oxygen were inadequate. It was necessary to start timing each reaction from the point of mixing, to the production of a stated volume of oxygen (or the volume at a stated time).

(b) The essential characteristic of a heterogeneous catalyst is its surface area, which was the required answer. A significant number of candidates had this but many coupled that with others, such as concentration, mass, temperature and other variables or had those variables on their own.

(c) Properly labelled axes were required and a line starting at the origin, showing the steepest slope at the origin. The commonest error here was giving a straight line from the origin. The line had to show no change in volume from 2 minutes. Most candidates gained credit for this. Some candidates did not provide a time scale so even though the graph was complete, no credit could be given.

(d) The hazards and precautions in this experiment were mostly done well. The Hazcard information was often used well. Poisonous had to be related to either or both solids (not chemicals, as hydrogen peroxide was also present) along with a face mask precaution. Irritation had to be related to lead(IV) oxide and gloves.

Question 3

Most candidates made good progress with this question.

(a) Virtually all of the candidates could correctly calculate the two values for M_r. Unfortunately, a minority incorrectly gave the M_r a unit, such as 'g'.

(b) (i) and **(ii)**
The majority of candidates coped well with this calculation. With minor exceptions, the candidates were able to present the mole fractions as a fraction. Most correctly showed the result by calculation. Some candidates did the calculation by way of vulgar fractions throughout (some calculators default to a fractional number), which candidates usually translated into the correct decimal statement.

(c) Most, but not all, candidates followed the instruction as to which variable was to be on each axis. Some did not label their axes or provide a unit for temperature.

The data was constructed to cover the grid well by having 10 small squares to be 0.1 mole fraction and 20 small squares to be 10°C, with the scale starting at 70 or 75°C. Some candidates chose to have an origin, which meant that the temperature scale was halved (10 small squares to be 10°C) and the plot was contracted into less than half of the available grid. There was very little use of inconvenient scales.

The commonest plotting errors were found where the temperature ended in 0.3 or in the omission of points (often at 120°C).

A significant number of candidates made a reasonable attempt at drawing two curves. Some candidates drew a straight line for the vapour data or occasionally two straight lines. A few candidates drew a vapour line that twisted and turned, connecting all the points including the deliberate anomaly. Not all of the liquid and vapour points fitted a smooth curve so some judgement was necessary as to where to run each curve. Some candidates deviated their curves into points that did not fit a smooth curve.

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(d) If correctly plotted, the most anomalous point was at point 3. If a straight line was drawn for the vapour then point 2 would have been the most anomalous result. It was necessary to point out only the most anomalous result. Some candidates chose more than one result and others chose points that were on the plotted line. Very few candidates had a reasonable explanation for their anomaly. The essential point was that the temperature of the analysis was too low. Many erroneous answers were concerned with loss of vapour, calculation error or experiment not done properly.

(e) Most candidates identified the 0.5 mole fraction point on the liquid line. Some did not realise that the production had to be at the same temperature and wrongly produced the line upwards. Most candidates drew a horizontal line, although some lines were not quite horizontal, to the vapour line and correctly read the mole fraction value.

(f) Very few candidates gained full credit. There was uncertainty about the error in each new temperature reading. Many candidates used 0.1 and 1 as errors, where the 1 degree thermometer only was involved. Also, most candidates did not use the boiling points of the two pure liquids but other temperatures. The treatment of errors, particularly percentage errors, is not well known.

(g) (i) The majority of candidates successfully chose CCl_4 as the first to distil.

(ii) Very few candidates referred to the comparison of the mole fraction of CCl_4 in the vapour and liquid phases. There were comparisons between the two different liquids and references to M_r, volatility and intermolecular forces of attraction.

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