CHEMISTRY

Paper 9701/11
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There was a significant number of good performances.

Thirteen questions can be said to have been found to be easier, with 60% or more of candidates choosing the correct response to **Questions 1**, **3**, **4**, **5**, **6**, **14**, **17**, **18**, **19**, **29**, **30**, **32** and **40**.

Six questions were found to be particularly difficult with 40% or less of candidates choosing the correct response to **Questions 8**, **13**, **23**, **24**, **34** and **37**.

Comments on specific questions

Question 8

33% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **A**, chosen by 36% of candidates. This suggests that over two thirds of candidates realised that 6 × 395 kJmol^{-1} had to be used first, giving –405 kJmol^{-1}, but some of these candidates did not go on to use the fact that bond energies are endothermic.

Question 13

39% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**, chosen by 27% of candidates. Solving this question required the production of an equation, the use of the stoichiometry to calculate 0.06 moles of HCl, and then the use of N = V × C. The number of steps involved has probably combined to make the question difficult to some.

Question 23

27% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 31% of candidates. The statistics suggest that many candidates may have guessed. 2-methylbutan-1-ol is the only one of the possible isomers that has a chiral carbon atom. Candidates who performed well on this question probably drew the four possible isomers on their question paper.

Question 24

28% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 29% of candidates. The statistics suggest that many candidates may have guessed. The question required candidates to realise first that a six-membered cyclohexyl ring cannot be planar as the bond angle will be close to 109.5°, so the answer is not **A** or **C**. Secondly candidates had to realise that a ring prevents the possibility of *cis-trans* isomers at a double bond, so the answer is **B**.

Question 34

39% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 24% of candidates. These percentages show that 63% of candidates knew that $AlCl_3$ and $MgCl_2$ give solutions in water of pH less than 7, but that many of these candidates also believed $NaCl$ to be alkaline. It is possible that this misconception arose due to confusion between $NaCl$ and $NaOH$.

Question 37

27% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 45% of candidates. Statement 1 is correct, but was not believed to be so by many candidates, possibly because they did not count the electrons in the first shell of the nitrogen atom. Statement 3 is incorrect, but was believed to be correct by the majority of candidates, possibly because they did not consider the pair of electrons in the coordinate bond to be “bonding electrons”.

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Paper 9701/12
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There was a significant number of very good performances.

Ten questions can be said to have been found to be easier with 70% or more of candidates choosing the correct response to **Questions 1**, **2**, **5**, **9**, **10**, **13**, **15**, **16**, **18**, and **27**.

Six questions were found to be particularly difficult with 30% or less of candidates choosing the correct response to **Questions 22**, **26**, **29**, **31**, **32** and **40**.

Comments on specific questions

Question 22

28% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 37% of candidates. The question rests on the word “yield”. Candidates choosing **A** did not appreciate that this reaction will give a high yield of 1-chloropropane.

Question 26

19% of candidates chose the correct answer, **D**. The other three answers were all chosen by over 20 % of candidates, so, guessing may have occurred. Candidates had to draw or imagine the five structural isomers of C_5H_{10} that are alkenes, and then they had to realise that pent-2-ene has *cis-trans* isomers, making six isomers in total.

Question 29

21% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**, chosen by 39% of candidates. The majority of candidates therefore appreciated that cold, dilute acidified $KMnO_4$ would add two chiral carbon atoms by producing a diol, but did not appreciate that concentrated acidified $KMnO_4$ would remove one chiral carbon atom as the HO– group on the left of the molecule is oxidised to a ketone.

Question 31

15% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 51% of candidates. This choice rests on believing that statement 2 is true. However, diluting the acid does not change the average energy of the reactant molecules, so the proportion of effective collisions <u>between</u> <u>reactant</u> <u>molecules</u> does not change.

Question 32

26% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 47% of candidates. Under a fourfold increase in pressure, the volume of an ideal gas will decrease here from 76.0 cm^3 to 19.0 cm^3. Statement 2 says “The gas partly liquefies”, but this would have produced a <u>lower</u> volume than 19.0 cm^3.

Question 40

16% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 65% of candidates. Therefore, the majority of candidates believed that statements 2 and 3 would produce “a salt with the empirical formula of $CaC_4H_6O_4$”. It is possible that they were lead to this assumption by the four carbon atoms in one molecule of butanedioic acid and in one molecule of methylpropanedioic acid. It might be expected that candidates who decided that statements 2 and 3 are correct would have gone on to answer **A**, since statement 1 <u>is</u> correct. However, there were very few – only 7% – who chose **A**. This suggests that the formula of the product of statement 1, $Ca^{2+}(CH_3CO_2^-)_2$, was not appreciated by many. This in turn suggests that candidates may have been very short of time when they reached this question, which was the last question on the paper.

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Paper 9701/13
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There was a significant number of excellent performances.

Eleven questions can be said to have been found to be easier with 80% or more of candidates choosing the correct response to **Questions 1**, **2**, **3**, **4**, **7**, **11**, **15**, **22**, **30**, **31** and **39**.

Five questions were found to be particularly difficult with 45% or less of candidates choosing the correct response to **Questions 25**, **26**, **27**, **33** and **34**.

Comments on specific questions

Question 25

40% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 31% of candidates. The question depends on the ability to draw or imagine all the primary alcohols with formula $C_5H_{11}OH$, and then to decide how many of them contain a chiral carbon atom. Only one of the isomers, 2-methylbutan-1-ol, does so, hence **B** is the answer.

Question 26

40% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 46% of candidates. The question depends on the ability to draw or imagine the isomers, both structural and geometric, formed by dehydrating different alcohols. **B** will produce four, cis and trans hex-2-ene and cis and trans hex-3-ene. **C** will only produce three, cis and trans 3-methylpent-2-ene and 2-ethylbut-1-ene. Candidates who chose **C** had possibly not appreciated the symmetrical nature of the alcohol in **C**. Dehydration of this alcohol across the bond to the left of the OH group (as drawn), and dehydration across the bond to the right of the OH group, produce the same products.

Question 27

31% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 44% of candidates. This is a difficult question, due to the complex nature of the cholesterol molecule drawn. Candidates choosing **C** believed that the rings were all planar, but the molecule has three six-membered rings that will not be planar.

Question 33

43% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B** with 33% of candidates choosing this answer. A significant percentage, 22%, chose **A**. Candidates who chose **B**, thinking statement 2 was correct, possibly assumed that sulfuric acid only acts as an acid with water, and did not appreciate that the lone pairs on the oxygen atom allow ethanol to act as a base. Candidates who chose **A** did not appreciate that the ammonium ion cannot accept a proton. The truth of statement 1 was clearly appreciated by most candidates.

Question 34

31% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 37% of candidates. A significant percentage, 27%, chose **A**. A large number of candidates therefore judged statement 3 to be true. This was possibly due to the incorrect assumption that a coordinate bond is not a “bonding pair of electrons”. Candidates who chose **C** did not think the ammonium ion “contains ten electrons”. This error will arise if the positive charge is not taken into account, or if the two electrons in the inner shell of the nitrogen atom are not taken into account.

CHEMISTRY

Paper 9701/21
AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.
- Care should be taken that all equations are balanced.

General comments

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

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

The more able candidates scored well on **Question 1**, coping well with the calculations, while **Questions 3** and **5** yielded good answers from many candidates. **Questions 2** and **4** involved much factual recall and indicated which candidates had concentrated on this aspect of their revision.

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

There was some evidence of candidates not checking their work before giving in their answer papers. Examples included unbalanced equations and different formulae representing the same compound in the same question.

Comments on specific questions

Question 1

The ability to carry out routine calculations on reacting masses and on the general gas equation is an important skill in AS Level Chemistry. While there were many correct answers to the calculations, a significant number of candidates struggled with at least one of the calculations, largely because they used a very unstructured approach to the problem.

(a) Most candidates deduced that $C_{14}H_{30}$ is an alkane. The small minority of candidates who gave 'hydrocarbon' as their answer received no credit.

(b) There were many correct equations given.

(c) Both parts of this question were well answered but some candidates were not credited for not giving their answer to one decimal place, as the question required.

(i) The correct answer is 88.5 t.

(ii) While the more able candidates gained full credit in this part, the most common mistake was to omit to use M_r of $C_{14}H_{30}$ = 198 in the calculation.

(d) To answer this question correctly, candidates had to use the appropriate units for volume and pressure and to convert the temperature into K. Not all were able to do this correctly.

(e) The more able candidates realised they did not have to use 2.8×10^4 Pa in their calculations.

Question 2

This question involved much factual recall on cracking, environmental issues and the Contact process. There were many good answers.

(a)

(i) This was well answered by the majority of candidates.

(ii) While many candidates gave a correct answer, some candidates discussed fractional distillation rather than thermal or catalytic cracking.

(iii) This was well answered.

(b) The majority of candidates realised ethanol contains hydrogen bonds which are stronger than the intermolecular forces in ethanethiol. A small number of candidates referred to the relative strengths of the O-H and S-H covalent bonds in these two molecules and received no credit.

(c)

(i) To answer this correctly, candidates needed to realise that as the question specified burning ethanethiol in an excess of air, the oxides formed would be CO_2, SO_2 and H_2O. Many candidates did not do this.

(ii) Most candidates knew the environmental consequences of the CO_2 and SO_2 produced and there were many good answers given.

(d) Many candidates successfully linked the smell of ethanethiol with it being useful in the detection of gas leaks.

(e) The conditions of the Contact process were well known and full credit was common. Candidates should realise that the oxidation number of vanadium in the oxide used as the catalyst should always be quoted to avoid any ambiguity.

Question 3

This question tested candidates' knowledge of the reactions of calcium and its compounds. There were many good answers but a significant number of candidates did not check their work carefully and gave answers with incorrect formulae and/or unbalanced equations.

(a) This was well answered with many candidates being awarded full credit for this part. However, other candidates gave answers in which the oxidation number of calcium varied from compound to compound and were penalised.

(b) Candidates were expected to state that **Y** needed heating which some candidates confused with burning or combustion.

(c)

(i) These reactions were usually well known with only occasional slips in balancing the equations.

(ii) The products of the thermal decomposition of calcium nitrate were less well known, oxygen often being omitted, or calcium a product.

(d) The formula of a soluble sulfate was needed. Barium sulfate was a common wrong answer while many answers contained an anion other than sulfate.

(e) Most candidates knew that in forming **X**, calcium dissolves with effervescence, leaving a white precipitate.

However, answers suggested that candidates had little experience of the second reaction - the formation of **X** from **V** - as an observation from the previous answer was often simply repeated. The vigorous and exothermic nature of the reaction was rarely stated.

Question 4

The use of 2,4-dinitrophenylhydrazine as a reagent is a key part of the chemistry of carbonyl compounds. This question involved knowledge of two of the basic reactions of propanone, with hydrogen cyanide and with 2,4-dinitrophenylhydrazine, rather than on the observations made when the latter reaction is carried out. There were many good answers.

(a)

(i) 'Nucleophilic addition' was known by the majority of candidates.

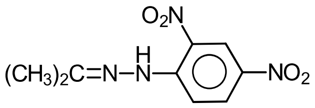
(ii) Candidates were less certain of the reagent, the CN^- ion often being omitted. Examiners were looking for answers such as NaCN and H_2SO_4, or HCN with a small quantity of NaCN or KCN present.

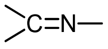
(iii) The dipole present in the propanone molecule was usually clearly shown.

(b)

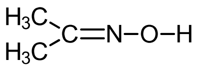
(i) Only the more able candidates scored full credit in this part, many candidates not realising that water is also produced in this condensation reaction.

The organic product formed is shown below.



Examiners expected candidates to show the  double bond, but this was not always done.

(ii) The way the formulae of the reactants were drawn on the question paper was intended to help candidates to deduce that water is also eliminated in this reaction. The final organic product is shown below.



Question 5

The application of knowledge of organic reactions to unfamiliar compounds is a demanding, but necessary, part of AS Level Chemistry. This question involved candidates applying their organic chemistry knowledge to unfamiliar situations, followed by a standard calculation in **(d)**. Many candidates gave good answers to **(a)** to **(c)** but **(d)** was often less well done.

(a) This was well answered.

(b)

(i) While many candidates deduced that step 1 is an addition reaction, fewer were able to work out that it was an electrophilic addition. Many stated correctly that step 2 is an elimination reaction.

(ii) Examiners expected candidates to apply their knowledge of the reactions of the halogenoalkanes to this elimination and to identify the reagent as NaOH in alcoholic solution. Candidates who gave NaOH(aq) in alcohol were penalised for a contradictory answer.

(c)

(i) There were many candidates who correctly identified **Q** as CH_3CHO and **R** as CH_3CO_2H. Those who wrote the structure of **Q** as CH_3COH were penalised.

(ii) Step 3 is an addition and step 4 an oxidation reaction. There were many correct answers.

(d)

(i) The correct equation for $\Delta H^{\ominus}_{c}$ of ethyne is as follows.

$$C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$$

Examiners required the equation to be written in terms of one mole of C_2H_2 and to contain fully correct state symbols. Ethyne is a gas (given in the first line of the question) and water a liquid under the conditions stated (298 K).

The equation for $\Delta H^{\ominus}_{f}$ of ethyne, which was less well known, is as follows.

$$2C(s) + H_2(g) \rightarrow C_2H_2(g).$$

Wrong equations often included oxygen and/or water, or represented the hydrogen as 2H(g).

(ii) This calculation follows from the previous equation. The more able candidates constructed the correct cycle to give the energy change as follows.

$$\Delta H^{\ominus}_{f} = 2(-394) + (-286) - (-1300) = +226\ \text{kJmol}^{-1}$$

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.
- Care should be taken that all equations are balanced.

General comments

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

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

The more able candidates scored well on **Questions 3** and **5**, showing good factual recall. **Questions 1** and **2** involved calculations which defeated many of those who did not adopt a logical approach to the task.

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

There was some evidence of candidates not checking their work before giving in their answer papers. Examples included unbalanced equations and different formulae representing the same compound in the same question.

Comments on specific questions

Question 1

The ability to carry out routine calculations on numbers of moles reacting and an equilibrium constant, K_c, is an important skill in AS Level Chemistry. While there were many correct answers to the calculations, a significant number of candidates struggled with at least one of them, largely because they used a very unstructured approach to the problem.

(a) Most candidates gave a correct expression for $K_{c.}$ A common mistake was to omit the term for water which is a reagent in this reaction and not a solvent which is present in an excess. A small minority of candidates expressed the concentrations of the chemicals as (CH_3CO_2H) etc. rather than $[CH_3CO_2H]$ etc. and were penalised.

Most candidates correctly stated that there were no units for K_c in this case. Examiners did not accept the numbers 0 or 1.

(b) While there were many correct answers to this part, a significant number of candidates made at least one error in the calculations.

(i) The majority of candidates gave the correct answer, 0.045 mol.

(ii) A significant number of candidates struggled with this part, not realising that 0.005 mol of hydrogen chloride would react with 0.005 mol of NaOH.

(iii) Most candidates gave a correct equation.

(iv) This was less well done with many candidates not realising that their answer was obtained by subtracting their value in **(b)(ii)** from their value in **(b)(i)**.

(c)

(i) To answer this question correctly, candidates had to use their answer to **(b)(iv)** to calculate the amount, in moles, of CH_3CO_2H present at equilibrium.

(ii) The answers to **(c)(i)** needed to be used to give a value for K_c.

(d) Only a small number of candidates gave a correct answer to this part. Examiners expected candidates to consider the nature of the two compounds that react with sodium hydroxide. Like sodium hydroxide, both ethanoic and hydrochloric acids are ionised. However, ethyl ethanoate is not ionic. This means that the activation energy of the reaction between sodium hydroxide and ethyl ethanoate will be higher than that for its reactions with the acids.

Some candidates simply said 'the activation energy is too high' without making it clear to which reaction they were referring. Examiners did not credit such answers.

(e) Many candidates correctly stated that more ester would be formed over a period of time. However, only a minority of them explained why this would be the case. Examiners expected an explanation in terms of the reaction moving to the right in order to restore the value of K_c or to restore the system to equilibrium. Answers that simply stated 'according to le Chatelier' were not accepted.

Question 2

A simple understanding of the enhanced greenhouse effect and of the effect of chlorofluoroalkanes on the ozone layer is a clear syllabus requirement - see *sections **10.2(i)*** and ***10.3(e)***. This question tested candidates' knowledge and understanding of these two different environmental problems. Answers showed that many candidates confused the two.

The first part of the question was a calculation to find a value for the C–F bond energy that many candidates carried out well.

(a) This was correctly answered by many candidates. The *Data Booklet* gives all of the required bond energy values. The correct calculation is given below.

Some candidates used wrong bond energy values, particularly when dealing with C=C and C–C bonds.

There was, however, a significant number of candidates who did not understand how to carry out a calculation of this type. Among this group there were those who did not know that bond making is exothermic and bond breaking is endothermic.

As with all calculations, a structured approach is more likely to yield the correct answer.

(b) The majority of candidates gave two correct properties.

(c) Although the question made reference to 'data from the *Data Booklet*', many candidates did not use the bond energy value for the C–Cl bond of 340 kJ mol^{-1} in their answer. There were, however, many correct references to the formation of the C$l^{\bullet}$ free radical.

(d) This part was less well answered with many candidates confusing the depletion of the ozone layer with the greenhouse effect.

(i) Only a minority of candidates knew that CO_2 traps heat reflected from the Earth in the lower atmosphere. More stated that the greenhouse effect leads to global warming with its consequences.

(ii) Many candidates knew that CO_2 is the second most abundant greenhouse gas.

(e) There were many candidates who correctly gave octahedral as the shape of the SF_6 molecule. This compound is specifically mentioned in syllabus *section **3(c)***.

Question 3

This question tested candidates' knowledge of the reactions of barium and its compounds. There were many good answers but a significant number of candidates did not check their work carefully and gave answers with incorrect formulae and/or unbalanced equations.

(a) This was well answered with many candidates being awarded full credit for this part. However, other candidates gave answers in which the oxidation number of barium varied from compound to compound and this was not credited.

(b)

(i) Most candidates gave a correct equation for the conversion of compound **T** to compound **W**. The most common mistake was to leave the equation unbalanced.

There were many correct equations for the roasting of **V** in air. The most common error was to attempt to react the $BaCO_3$ with oxygen.

(ii) Most candidates correctly gave CO_2 as the gaseous reagent. Some candidates did not read the question carefully enough and suggested aqueous solutions such as Na_2CO_3(aq) which Examiners did not allow.

(c) This was less well answered. Examiners expected aqueous solutions of salts such as Na_2SO_4 but some of the compounds offered were insoluble sulfates such as $CaSO_4$ or $PbSO_4$. As with the previous part some candidates did not read the question carefully and suggested sulfuric acid.

(d)

(i) The majority of candidates correctly calculated the empirical formula as BaO_2. The most common error was to use the proton number of barium (56) rather than its relative atomic mass (137).

(ii) Although BaO_2 is unfamiliar to AS Level candidates, the extremely insoluble nature of $BaSO_4$ should not be and many candidates correctly identified the latter compound as the solid **Y**.

(iii) Many candidates correctly gave the following equation.

$$BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2$$

However, a significant number of answers showed that candidates had not checked to see if their equation was balanced, with H_2O being a common (wrong) product.

Question 4

Knowledge of the manufacture of chlorine by electrolysis using a diaphragm cell is referred to in syllabus ***section 6(b)***. There were many good clear diagrams which showed that these candidates had learned the required material. However, some diagrams suggested that this topic was unfamiliar to some candidates.

(a)

(i) Most diagrams clearly showed correctly labelled inlets and outlets, and electrodes. A small number of candidates used platinum as their electrode materials and this was not credited. The question referred to the manufacture of chlorine in a diaphragm cell and Examiners gave no credit to diagrams which showed how such an electrolysis might be carried out in a school or college laboratory.

(ii) Most candidates gave two fully correct equations with state symbols. Common errors were to omit or give incorrect state symbols, or to give the equation for the production of chlorine at the cathode.

(iii) The most common answer was 'NaOH' - despite candidates being asked to give 'the name of the chemical that is produced in solution'.

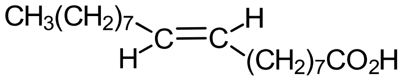
Question 5

The application of knowledge of familiar reactions to unusual compounds is a demanding, but necessary, part of AS Level Chemistry. This question involved candidates using their knowledge of organic chemistry to deduce what would be formed when unfamiliar compounds were reacted with familiar reagents. There were many good answers.

(a) This was well answered by those candidates who understood that all three of the alcohol groups in glycerol had to react with stearic acid in order for the compound to be 'completely esterified'. However, a significant number of candidates did not do this and were not credited.

(b) Many candidates answered this part in terms of an aqueous acid such as sulfuric acid or hydrochloric acid. Those candidates who carried out the hydrolysis using aqueous alkali generally did not acidify the product and received no credit. Examiners did not allow concentrated sulfuric acid which would cause other side-reactions to occur.

(c) There were many candidates who gave the correct *cis* structure for elaidic acid, as shown below.



The most common error was to include one or two extra $>C-H$ groups between the alkene group and the $-(CH_2)_7-$ chains.

(d)

(i) This was less well answered. Many candidates referred to 'double bonds' without making a specific reference to $>C=C<$ double bonds which Examiners did not accept. There was a significant number of candidates who assumed that the prefix 'poly' implied a polymer which is not correct in this case.

(ii) Most candidates gave the correct reagent and conditions - hydrogen and a nickel catalyst.

(e)

(i) This was well answered by the majority of candidates.

(ii) The majority of candidates gave the correct reagent - 2,4-dinitrophenylhydrazine - but not all of these gave the correct result of its use. Examiners expected candidates to state that a yellow or orange precipitate would be formed. Those who referred to a colour change were given no credit.

(iii) This was generally well answered with the majority of candidates choosing a suitable reagent and giving the correct result. As with **(e)(ii)**, Examiners expected reference to a precipitate and not to a colour change.

(f)

(i) Fewer candidates correctly deduced that ascorbic acid contains two chiral carbon atoms in its molecule.

(ii) This was even less well answered with only a minority of candidates deducing that ascorbic acid contains an ester group.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.
- Care should be taken that all equations are balanced.

General comments

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

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

The more able candidates scored well on **Question 1**, coping well with the calculations, while **Questions 3** and **4** yielded good answers from many candidates. **Questions 2** and **3** involved much factual recall and indicated which candidates had concentrated on this aspect of their revision.

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

There was some evidence of candidates not checking their work before giving in their answer papers, unbalanced equations often being written.

Comments on specific questions

Question 1

The ability to handle numerical data and to carry out calculations correctly is an important skill for AS Level candidates to have. The ability to express numerical values to an appropriate number of significant figures is equally important.

In this question, candidates were asked to carry out a number of calculations and give each answer to two significant figures. While many candidates did this, there was a significant number who did not give all of their values to two significant figures. Centres are reminded that syllabus *section **1(h)*** refers to this matter.

(a)

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

(ii) This part was usually correctly calculated but many candidates gave their answer to three significant figures and were penalised. The correct answer is obtained by dividing 7.5×10^{-3} by 2 which gives 3.75×10^{-3} cm^3. Many candidates left their answer in this form and were penalised. The correct answer is 3.8×10^{-3} cm^3.

(iii) The majority of candidates carried out this calculation correctly, although many did not reduce their answers to two significant figures. A small number actually stated that they had given their answer to three significant figures.

(b)

(i) This was correctly answered by the majority of candidates. A small number of candidates, who gave all their other answers to two significant figures, gave this one as $3 \times 10^{-3}\,cm^3$ and were not credited.

(ii) This too was correctly answered by most candidates.

(c)

(i) Many candidates struggled to construct the following equation.

$$HCO_2H + NaHCO_3 \rightarrow HCO_2Na + H_2O + CO_2$$

There were many answers in which the hydrogen atom of the hydrocarbon chain was replaced by sodium - i.e. the carboxylic acid group remained unchanged. Other candidates gave Na, Na_2O, NaOH, Na_2CO_3 or NaH as products.

(ii) This was well answered by many candidates but less well so than the earlier calculations. Examiners made allowance for those candidates who made an error in the stoichiometry of their equation in **(c)(i)**.

Question 2

There were some good answers to all parts of this question although few candidates were able to give a fully correct answer. An understanding of the forces which hold atoms within molecules and which hold molecules together is important in explaining some of the physical properties of compounds. It was apparent that many candidates confused intermolecular forces with covalent bonds.

(a) The majority of candidates gave two correct assumptions of the kinetic theory.

(b) Fewer candidates were able to give two correct conditions under which the behaviour of a real gas approaches that of an ideal gas.

(c) The majority of candidates gave the correct order of gases. However, only a very small number of candidates gave a fully correct explanation of this order in terms of the intermolecular forces present. A popular wrong answer was to attribute the difference between neon and nitrogen to the strong $N\equiv N$ bond in nitrogen. Similarly, many candidates thought that the dipole in ammonia would produce a stronger intermolecular force than the hydrogen bonds that are present.

(d) There were many good answers to this part. Those candidates who did not gain full credit usually did not discuss the strength of the intermolecular forces, with many of them referring to activation energy, E_a, even though no chemical reaction was taking place.

(e) This was answered correctly by the majority of candidates who deduced that there are 18 electrons in each molecule.

(f)

(i) This was less well answered than some earlier parts. Although the numbers of electrons had been asked for in **(e)**, many candidates did not link this to the explanation of the similarity in boiling points in terms of van der Waals' forces.

(ii) This was slightly better answered than **(f)(i)**. However, a significant number of candidates either referred incorrectly to hydrogen bonding or to the C—F bond being stronger than the C—H bond.

Question 3

A good knowledge and understanding of the trends in physical properties across the period from Na to Ar is an essential part of inorganic chemistry at AS Level. As with the previous question, there were many good answers to individual sections of the question but very few candidates gave fully correct answers.

(a) Most candidates drew an acceptable graph which showed the general decrease in atomic radius across the period. While many candidates knew that the nuclear charge increases across the period, fewer knew that each extra electron is added to the same shell.

(b) There were fewer acceptable graphs in this part, the most common error being not showing silicon as having the highest melting point. Many candidates explained the differences in melting point in terms of metallic bonds for Na to Al, a giant covalent structure in Si and simple covalent P to Cl. However, some candidates could not be credited as they did not make it clear which bonding type referred to which element.

(c) Many of the sketch graphs in this part were incorrect due to the position of Si. There were many good explanations of the increase in conductivity from Na to Al, and for the very low conductivity of P to Cl. Fewer candidates stated that Si is a semi-conductor.

(d)

(i) The bonding in the first two compounds was correctly stated by most candidates. For the third compound, there were fewer correct answers with many candidates stating that covalent bonds would be broken when P_4O_6 is melted.

(ii) This was very well answered with almost all candidates choosing either Al_2O_3 or SiO_2.

Question 4

This question tested candidates' knowledge of some important reactions in organic chemistry. Many candidates demonstrated reasonable knowledge of the reactions involved although only a minority gave fully correct answers.

(a) Almost all candidates gave the correct empirical formula, $C_9H_{16}O_2$.

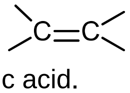
(b)

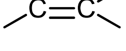
(i) The question asked candidates to 'Name as fully as you can ...' two functional groups. Examiners expected candidates to give the answers 'aldehyde' and 'secondary alcohol'. A significant number did not read the question carefully enough and gave one or both of the ambiguous answers 'carbonyl' and 'hydroxyl'. Examiners did not accept either of these responses.

(ii) The majority of candidates chose bromine as the reagent and described how the solution would become colourless. Those candidates who stated that the solution would become 'clear' were not given any credit. A small number of candidates did not state what would be seen when the reaction is carried out and were penalised.

(c) The skill required in this part was to decide which of the functional groups present would react with the given reagent. There were many good answers but there were also many candidates whose knowledge of the reactions involved was not quite secure.

A small number of candidates gave skeletal formulae instead of structural formulae and were penalised.

(i) This part was poorly answered with many candidates not recognising that the  bond would be broken to give two compounds, each of which would be a carboxylic acid.

(ii) This was fairly well answered although there were many candidates who thought that PCl_3 would cause the addition of Cl_2 across the  bond.

(iii) This too was fairly well answered although some candidates, who clearly knew that $NaBH_4$ would only reduce the –CHO group, were penalised for giving an incorrect structural formula of the resulting compound.

Question 5

This question was concerned with more organic reactions and with structural isomerism. There were many good answers to the factual chemistry parts of the question but few candidates were able to give a fully correct isomer in the last part.

(a)

(i) Almost all candidates gave the correct molecular formula, $C_7H_{14}O_2$.

(ii) The majority of candidates correctly deduced that there is one chiral carbon atom present in a molecule of 2-ethyl-3-methylbutanoic acid.

(b)

(i) Many candidates correctly chose an acidified solution of potassium dichromate(VI) as their oxidant. Those candidates who omitted to state that the reagent was acidified were not credited. The change in colour was usually correct.

(ii) Fewer candidates understood that the alcohol is oxidised to aldehyde and then to carboxylic acid and were thus unable to identify the main organic impurity present in the acid.

(iii) Although **(b)(ii)** was relatively poorly answered, this part received more correct answers. A small number of candidates simply stated ‘reflux’ without an explanation and received no credit.

(c) There were many incorrect answers to this part, because the candidates believed that the isomer 2-ethyl-3-methylbutan-2-ol is a secondary alcohol. Some then thought that this would be oxidised and described a colour change, while others stated that it would not be oxidised and therefore there would be no colour change.

(d) There were very few fully correct answers to this part. The question stated that the isomer ‘is an ethyl ester’ and ‘contains a branched hydrocarbon chain’. Despite this, few of the esters given in answers were ethyl esters.

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Paper 9701/31
Advanced Practical Skills

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
- In quantitative experiments, candidates should record readings from the equipment to an appropriate level of accuracy and numeric answers to calculations should be given to an appropriate number of significant figures.
- In qualitative experiments, candidates should be reminded of the importance of making complete and accurate notes of their observations. When a gas is observed this gas should be tested, the observations of the test recorded and the gas identified.

General comments

Thank you to Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the Examiners expect to see in the script packet for each Session and for each Laboratory within a Session the following documentation:

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

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular Session/Laboratory and to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, the Examiners would appreciate it if all Centres running more than one Session, and/or using more than one Laboratory, would instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

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

There was little evidence of candidates not finishing the paper in the allocated time as most completed all the questions.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work in the question successfully, and most were able to gain credit in the early stages of the calculation.

(a) The majority of candidates gave a value for the rough titre and burette readings for the accurate titres as instructed, and gave appropriate headings for the rough and accurate titration tables. However, there are still Centres whose candidates do not give burette readings to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to squander time by carrying out a third accurate titration when the previous two were within 0.10 cm^3. These candidates ran the risk of the third titre not being concordant thus necessitating a fourth accurate titration.

(b) The majority of candidates selected appropriate titres for their mean. However, a number used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range. Some candidates clearly carried out the calculation correctly but their work could not be credited since they rounded their final answer incorrectly.

(c) In this section candidates were instructed to show working and quote answers to an appropriate number of significant figures. Credit could be gained for showing working, even if the actual numerical value was incorrect, and answers given to 3 or 4 significant figures were considered acceptable.

(i) This part was answered well by most candidates.

(ii) A few candidates inverted the mole ratio but this part was generally well answered.

(iii) Weaker candidates tended to use the approximate concentration (0.7 mol dm^{-3}) of sulfuric acid rather than use their answer in **(ii)**. Some of these candidates did not complete the rest of the section. However, candidates are advised always to attempt questions since even incorrect numerical values can be used to gain credit in later parts of the calculations.

(iv) Those completing **(iii)** were usually able to finish the calculation successfully.

Question 2

The majority of candidates appeared well-prepared for the practical section of this type of question and performed well here.

(a) In recording results of experiments using thermometers calibrated to 1 °C, candidates should ensure they quote all thermometer readings to the nearest 0.5 °C and be careful that all readings are shown with relevant units. The majority of candidates gained at least partial credit.

(i) Most candidates were clearly aware of the need to use $mc\Delta T$ and correctly calculated the heat energy produced. A small number quoted incorrect units, most commonly kJ when a division by 1000 had not been applied, kJ mol^{-1} or units involving g or cm^3 in some way.

(ii) For credit in this part the final answer had to be given to 3 significant figures as instructed. Many candidates correctly used the fact that 0.016 moles of sulfuric acid were involved but others merely restated their answer to **(i)** or divided it by 1000.

(b) The use of 0.5 °C accuracy and correct units also applied to the results in this section. The majority of candidates gained at least partial credit for accuracy.

(i)(ii) Candidates who were able to calculate the enthalpy change in **(a)(i)** were generally able to apply similar knowledge in **(b)(i)**. It was however necessary to use 0.032 moles of reagent in **(ii)**.

(iii) A significant number of candidates omitted this part. However a large number used Hess' Law to calculate the enthalpy change. Credit was given for answers that followed from **(a)(ii)** and **(b)(ii)** even if these answers were numerically incorrect.

(c) Most candidates gave an acceptable method of limiting heat loss with the suggestion of the use of a lid being the most common.

Question 3

It was apparent that this question caused the candidates the most difficulty. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is not possible to answer such questions by rote as decisions have to be made as to the suitability of reagents and the likely outcomes of the tests using them. The majority of the candidates observed the instruction to give the correct full names or formulae for the reagents selected.

(a)

(i) The expected outcome was no visible reaction (no precipitate, no change) but some candidates reported a slight white precipitate with aqueous silver nitrate. It is important that solutions of reagents to be available in a practical examination are freshly prepared using distilled or deionised water, or that existing reagents are checked for contamination.

(ii) The instruction was that candidates should 'record the observations made at each stage' so separate results were needed for gentle heating, then strong heating and finally when the tube was left to cool. Few candidates made it clear at what stage the observation they made applied.

(iii) The deduction had to follow evidence so that the observation of a brown gas in **(ii)** should have allowed the candidates to suggest the presence of nitrate or nitrite.

(iv) Credit was given if candidates either used aqueous sodium hydroxide and aluminium to show that a nitrate or nitrite was present or used a dilute acid to show which of these ions was present. Some candidates gave correct observations but did not use them to reach any conclusion.

(v) This part was well done with most candidates using aqueous ammonia to correctly identify the presence of Zn^{2+}.

(b)

(i) Candidates were expected to observe the blue/black coloration of the starch iodine complex and also the formation of a precipitate (of copper(I) iodide). While most gave correct colour changes some described the test tube as containing solutions rather than recognising that a solid had been formed.

(ii) There seemed to be some confusion about whether iodide or iodine had been formed and in which direction the redox lay. Many candidates clearly recognised that the formation of the blue/ black coloration in **(i)** was linked, in some way, with iodine.

(iii) It appeared, from the answers given, that some candidates added sodium hydroxide to their tube from **(ii)** rather than to **FA 8**. Most, who used the correct solution, obtained acceptable observations. It was clear that many candidates were familiar with the half-equation $Cu^{2+} + 2e^{-} \rightarrow Cu$ but few used OH^{-} successfully in a balanced ionic equation.

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Paper 9701/32
Advanced Practical Skills

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
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Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence.

It was evident that most candidates were familiar with the types of calculations included and the use of the Qualitative Analysis Notes. There was little evidence of candidates not finishing the paper in the allocated time as most completed all the questions.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work successfully, and most were able to gain credit in the early stages of the calculation. More able candidates showed their skill in moles based calculations by producing logical, clearly set out responses.

(a) The question stated that candidates should record the mass of the tube containing **FB 1** and the mass of the tube with any residual **FB 1**, as well as the results for a rough titration and accurate titrations. Most candidates obeyed these instructions and recorded results in an appropriate format. However, there are still Centres whose candidates do not give burette readings to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to squander time by carrying out a third accurate titration when the previous two were within 0.10 cm^3. These candidates ran the risk of the third titre not being concordant thus necessitating a fourth accurate titration.

(b) The majority of candidates selected appropriate titres for their mean. However, a number used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range. Some candidates clearly carried out the calculation correctly but their work could not be credited since they rounded their final answer incorrectly.

(c) In this section, candidates were instructed to show working and quote answers to an appropriate number of significant figures. Credit could be gained for showing working, even if the actual numerical value was incorrect, and answers given to 3 or 4 significant figures were considered acceptable.

(i) Most candidates were able to calculate the number of moles of hydrochloric acid with only a small number omitting the 1000 needed to change cm^3 into dm^3.

(ii)(iii) The need to use the factor of 2 from the equation and then the factor of 10 was generally recognised with only a few candidates multiplying rather than dividing or trying to use another number in their calculations.

(iv) The majority of candidates were able to use the mass of **FB 1** they had weighed and the number of moles they had calculated in **(iii)** to find a relative formula mass.

(v) Credit was given for using 106 (the relative formula mass of Na_2CO_3) and their value of the relative formula mass of the hydrated compound even if the answer obtained was not chemically feasible. It is important that candidates realise that credit can be gained if measured or calculated values are used logically even if the answer obtained is not realistic.

(d) Even though questions on percentage errors inherent in apparatus have appeared on previous papers, only a minority of candidates gained credit here as many did not double the single error when calculating the percentage error in the titre.

Question 2

The majority of candidates appeared well-prepared for the practical section of this type of question. The more able candidates displayed clarity of thought in the calculation while weaker candidates were able to use standard formulae correctly to gain credit.

(a) In recording results of experiments using thermometers calibrated to 1 °C, candidates should ensure they quote all thermometer readings to the nearest 0.5 °C and be careful that all readings are shown with relevant units. The majority of candidates gained at least partial credit.

(b)

(i) Most candidates were clearly aware of the need to use $mc\Delta T$ and correctly calculated the heat energy produced. The most common error was to use the mass of **FB 3** for *m* instead of the volume of **FB 4**. There was a prompt to use the latter given in the units for *c*.

(ii) Most candidates were aware of how to calculate the number of moles and used a relevant relative formula mass, even if they had not completed the calculation in **1(c)(iv)**.

(iii) For credit in this part the final answer had to be given to 3 significant figures and to have the correct sign for the enthalpy change of the reaction. A number of candidates clearly knew how to use the data but did not satisfy one or both of these requirements.

(c) Some well-reasoned answers were seen but a large number of candidates apparently ignored the part of the question that stated that they should look at modifications apart from those designed to minimise heat transfer. Answers based on increased insulation and/or the using of a lid were therefore not acceptable. Other candidates recognised that the thermometer used was a major source of error but merely suggested using a more accurate one without actually specifying how this could be achieved.

Question 3

This question gave candidates who were able to think through the problem set logically rather than merely to quote the Qualitative Analysis Notes, the opportunity to show their understanding and some excellent answers were seen.

(a)

(i) It appeared that many candidates, when faced with a choice of the reagents, automatically chose aqueous sodium hydroxide and aqueous ammonia without actually considering their suitability for the ions to be identified. Since aqueous ammonia will not distinguish any of the cations in this case, a large number of unacceptable answers were seen. It was expected that, having eliminated Mg^{2+} by using aqueous sodium hydroxide to excess, candidates would use one of the variety of reagents that would indicate the presence of Pb^{2+}.

(ii) Candidates should be made aware that the identification of ions, and the evidence to support the identifications, must follow the observations made. Credit was possible for incorrectly identified ions provided the observations supported these. Able candidates gave precise evidence but weaker ones often omitted vital details such as the fact that a precipitate dissolved, or did not dissolve, in excess reagent. Some wrote that ‘it’ dissolved or did not dissolve in excess without clarifying what ‘it’ referred to.

(b)

(i) In general, if a gas is evolved, candidates should test the gas in order to identify it but in this case it was felt that the small volume of hydrogen given off would make this difficult. Therefore credit was given if the effervescence was recorded. Unfortunately there are still candidates reporting ‘gas evolved’, which is an inference, rather than the observation of effervescence, fizzing or bubbles.

(ii) The test to show the evolution of ammonia was required in this part, and many candidates were successful in gaining credit for this.

(iii) Most candidates recorded the formation of green and then brown precipitates. It is important that the state (precipitate or solution) is recorded as well as the colour seen.

There were many correct answers given for the identification of Fe^{2+} in **FB 8** and its changes in oxidation state. The change from +2 to 0 in **(i)** was the one that was least recognised but the majority of candidates correctly identified the +2 to +3 change in **(iii)**.

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Paper 9701/33
Advanced Practical Skills

Key messages

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

There was little evidence of candidates not to finishing the paper in the allocated time although some weaker candidates appeared to rush or omit either parts of the calculations or the later parts of **Question 3**.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work successfully in the question, and most were able to gain credit in the early stages of the calculation.

(a) The majority of candidates gave a value for the rough titre and burette readings for the accurate titres as instructed, and gave appropriate headings and units for the weighing and accurate titration in tables. However, there are still Centres whose candidates do not give burette readings to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to squander time by carrying out a third accurate titration when the previous two were within 0.10 cm^3. These candidates ran the risk of the third titre not being concordant thus necessitating a fourth accurate titration.

(b) The majority of candidates selected appropriate titres for their mean. However, a number used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range.

(c) More able candidates set the work out clearly and elegantly. Most candidates showed their working and many recorded their final answers to 3 or 4 significant figures.

(i) Almost all candidates were able to calculate the number of moles of MnO_4^-.

(ii)(iii) The majority were able to use the mole ratio correctly. Weaker candidates tended to use the formula mass of iron instead of multiplying by 10 in **(iii)**, and this made access to credit in **(iv)** difficult.

(iv) Many candidates used the formula mass of iron and the mass of **FA 1** weighed out correctly but not all gave the final answer to 3 or 4 significant figures.

(d)

(i) The majority of candidates were able to gain credit here although a few did not give an appropriate error for the balance used in **(a)**.

(ii) Even though questions on percentage errors inherent in apparatus have appeared on previous papers, only a minority of candidates gained credit here as many did not double the single error when calculating the maximum percentage error in the mass of **FA 1** used.

Question 2

The majority of candidates performed well in the practical section of this question. Weaker candidates found the calculation demanding, and relatively few were able to suggest a suitable improvement in the practical procedure given in **(a)**. It was particularly difficult for candidates in Centres providing lids for the crucibles to give an appropriate improvement. It is important that Centres set out only the apparatus listed in the Confidential Instructions, although candidates may ask for and be given extra items.

(a) Most candidates recorded all their balance readings to a consistent number of decimal places. However, some confused the mass of residue with the mass of water lost, and many did not re-heat to constant mass which is one of the classic techniques at AS Level. A small proportion of candidates re-heated after attaining constant mass and thus spent unnecessary time on this section. The majority of candidates gained at least partial credit for accuracy.

(b) There was more than one valid method of calculation for this section and the more able candidates gained full credit. Weaker candidates tended to stop after calculating the formula mass of **FA 4**.

(c) The majority of candidates answered this section in terms of heating to constant mass although they were prompted to do this in **(a)** in the instruction ‘Repeat the cycle of heating and weighing as many times as you think necessary’. A few candidates appeared confused as they answered in terms of heat loss. Others suggested that repeating the experiment would increase its accuracy. However, all three improvements listed in the mark scheme were seen.

Question 3

It was apparent that this question caused the candidates the most difficulty. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is not possible to answer such questions by rote as decisions have to be made as to the suitability of reagents and the likely outcomes of the tests using them. However, the majority of the candidates observed the instruction to give the correct full names or formulae for the reagents selected.

(a) The majority of candidates did not appear to heat **FA 5** gently at first and so missed the condensation forming further up the boiling tube. Even fewer tested any gas evolved with limewater though it was possible to be awarded credit for this in **(d)**.

(b) A large majority of candidates gained credit for the unambiguous layout of the tests and observations. The majority of candidates gained at least partial credit for observations though there are still candidates writing about red litmus turning blue without reference to a gas being tested. Some candidates appeared unsure of the correct description of the silver bromide precipitate and should be encouraged to use the descriptions given in the Qualitative Analysis Notes. Those with correct observations had no difficulty identifying the ions in **FA 6**.

(c) The candidates' descriptions of observations varied considerably and the appearance of misty or steamy white fumes was often overlooked. The colour of gas evolved was often omitted or given incorrectly as brown or yellow. Many candidates also mistakenly described the solid as forming a red/orange precipitate on addition of the concentrated acid, and many also ignored the instructions and so recorded observations after adding water. Some recorded 'it' going orange without stating what 'it' referred to. A small minority of candidates successfully tested the gas(es) evolved with acidified potassium dichromate paper though the bleaching of litmus paper was seldom reported. A variety of answers were given in the conclusion but correct answers were not always accompanied by an appropriate justification: many candidates knew that concentrated sulfuric acid is an oxidising agent but did not mention bromide ions being oxidised to bromine.

(d) Few candidates recorded effervescence on the addition of **FA 7** to the residue from **(a)**. It was possible for candidates to gain credit for the limewater test in this section and a few succeeded. Almost all candidates reported a white precipitate with lead nitrate but a disappointing number recorded a 'white solution' or a precipitate with silver nitrate. It is important that solutions of reagents to be available in a practical examination are freshly prepared using distilled or deionised water, or that existing reagents are checked for contamination.

(e) A substantial proportion of candidates did not appear to understand the instruction to select tests to confirm the identity of each of the two ions in **FA 7**. Many repeated the tests carried out in **(c)** and some selected a combination of aqueous sodium hydroxide and aqueous ammonia. Those choosing to test with barium chloride or nitrate did not always include the name of the acid added after the formation of the precipitate or gave sulfuric acid. However, a good number of candidates were able to identify the presence of sulfate ions. Some candidates mistakenly identified the solution tested as barium sulfate and should be encouraged to consult the Qualitative Analysis Notes more thoroughly. It is possible that candidates missing the effervescence in **(d)** did not consider **FA 7** being an acid and so very few gave an appropriate test for hydrogen ions.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills

Key messages

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- In qualitative experiments, candidates should be reminded of the importance of making complete and accurate notes of their observations. When a gas is observed this gas should be tested, the observations of the test recorded and the gas identified.

General comments

Thank you to Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the Examiners expect to see in the script packet for each Session and for each Laboratory within a Session the following documentation:

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

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular Session/Laboratory and to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, the Examiners would appreciate it if all Centres running more than one Session, and/or using more than one Laboratory, would instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

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

There was little evidence of well-organised candidates not finishing the paper in the allocated time although some weaker candidates appeared to rush or omit either parts of the calculations or the later parts of **Question 3**.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work successfully, and most were able to gain credit in the early stages of the calculation.

(a) The vast majority of candidates gave a value for the rough titre and burette readings for the accurate titres as instructed, and also diluted a volume of **FB 1** in the range given. However, there are still Centres whose candidates do not give burette readings to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to squander time by carrying out a third accurate titration when the previous two were within 0.10 cm^3. These candidates ran the risk of the third titre not being concordant thus necessitating a fourth accurate titration.

(b) The majority of candidates selected appropriate titres for their mean. However, a number used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range. Candidates should ensure that the mean is calculated to an appropriate number of decimal places and is correctly rounded.

(c) In the main, candidates displayed their working with clarity, although sometimes the working out of ratio expressions could have been shown more clearly. Generally it was the weaker candidates who did not provide answers to the expected 3 or 4 significant figures though some others rounded their final answers to only 2.

(i) Most candidates were able to evaluate this part correctly although a few gave the answer to an incorrect power of 10.

(ii)(iii) Many were able to use the mole ratios correctly.

(iv) Weaker candidates were more likely to use the ratio of 250:25 instead of the value of the mean titre in this part.

(v) Candidates found the last part of the calculation less challenging and it was often answered correctly.

(d) Almost all candidates calculated the maximum percentage error correctly for the volume pipetted into the conical flask. Even though questions on percentage errors inherent in apparatus have appeared on previous papers, only a minority of candidates gained credit here as the majority did not double the single error when calculating the percentage error in the titre. However, some attempts at a rigorous error analysis were seen.

Question 2

The majority of candidates were able to carry out the practical procedure successfully. However, many of the answers in other sections were not fully developed.

(a) The majority of candidates followed the instructions and completed the experiment and recorded results as required. Most included units with the headings though the unit for 1/time (s^{-1}) appeared less well known. However, a large minority of candidates did not record time to the nearest second. The majority selected volumes of **FB 6** and water to give a good range of results. Many candidates gained at least partial credit for accuracy.

(b) Answers to this part were rather poor with many candidates using phrases such as ‘fair test’ and ‘controlled variables’. The most common pertinent answer was in terms of keeping the depth of solution constant.

(c) This section was well answered by many, and some candidates went on to explain the relationship between concentration and rate in terms of collisions of particles. Credit was awarded for stating the relationship provided the practical results in **(a)** supported the conclusion. Some weaker candidates answered in terms of volume or merely reiterated the relationship between time and rate.

(d) Only a minority of candidates gained credit as most responses were too vague. Often one of the candidate’s experiments was chosen without giving sufficient reason for ‘greatest error’. However, some responses were excellent showing a clear understanding of the increase of percentage error with the decrease in time taken or the increased uncertainty in judging when the printing was obscured as the time taken increased.

(e) The majority of candidates did not give sufficient practical detail to gain credit. Weaker candidates tended merely to state how changing the concentration of acid would affect the rate. The most common omission was keeping the total volume constant.

Question 3

It was apparent that this question caused the candidates the most difficulty. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is not possible to answer such questions by rote as decisions have to be made as to the suitability of reagents and the likely outcomes of the tests using them. However, the majority of the candidates observed the instruction to give the correct full names or formulae for the reagents selected.

(a) Almost all candidates laid out the tests and observations clearly. However, the majority incorrectly selected aqueous sodium hydroxide in conjunction with aqueous ammonia. A number of those who did not select aqueous sodium hydroxide chose to use aqueous barium chloride to identify the solution containing lead ions. This reagent was not suitable as any salt containing sulfate ions would also give a white precipitate. However, credit for observation was available with the use of this reagent. The more able candidates generally chose to use hydrochloric acid or potassium chromate in addition to the aqueous ammonia.

(b) Greater precision is generally required in the answers to this type of question. Although candidates using sodium hydroxide and ammonia recorded identical observations for **FB 7** and **FB 9** most did not use this information to state that the salts both contained either aluminium or lead ions. Many candidates justified their choice of ion by writing about insoluble or soluble precipitates without mentioning the use of excess ammonia. Others wrote that ‘it’ dissolved or did not dissolve in excess without clarifying what ‘it’ referred to. Credit for identifying **FB 7** as $A\ell^{3+}$ was awarded least frequently as candidates needed to include that there was no reaction with the second reagent. However, there was an increase in the number of candidates giving the correct charges for the ions.

(c)

(i) The majority of candidates did not appear to heat **FB 10** gently at first and so missed the condensation forming further up the hard-glass tube. Even fewer tested any gas evolved with limewater.

(ii) Many candidates did not report further than slight effervescence when adding **FB 10** to aqueous copper sulfate and missed the blue or blue-green precipitate forming.

(iii) A far greater proportion of candidates gained credit for effervescence in this part. Unfortunately there are still candidates reporting ‘gas evolved’, which is an inference, rather than the observation of effervescence, fizzing or bubbles.

(iv) The majority of candidates performed well reporting the expected observations.

(v) Only a small minority heated the contents of the evaporating dish sufficiently as few reached the stage of black solid remaining.

(d)

(i) Credit was awarded here most frequently as many candidates selected sulfite for the anion in **FB 10** giving appropriate evidence from their observations in **(c)(iv)**. A smaller proportion of candidates correctly identified carbonate either from effervescence in **(c)(iv)** or from a successful limewater test somewhere in **(c)**. A few suggested hydrogen carbonate but without reporting water driven off in **(c)(i)**. It is important that conclusions are linked to relevant observations.

(ii) There was evidence of rushing in the last parts of this section as there were many inappropriate answers to **(ii)** such as acid-base or redox. As the solid had been heated strongly the expected response was thermal decomposition.

(iii) Only a small proportion of candidates correctly identified aqueous aluminium sulfate as being acidic or that the reaction was endothermic having reported the test-tube becoming cold in **(c)(iii)**. Again, it is important that conclusions are backed up by relevant observations.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills

Key messages

- As always, candidates should be encouraged to read each question carefully before answering or starting any practical work.
- In quantitative experiments, candidates should record readings from the equipment to an appropriate level of accuracy and numeric answers to calculations should be given to an appropriate number of significant figures.
- In qualitative experiments, candidates should be reminded of the importance of making complete and accurate notes of their observations. When a gas is observed this gas should be tested, the observations of the test recorded and the gas identified.

General comments

Thank you to Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the Examiners expect to see in the script packet for each Session and for each Laboratory within a Session the following documentation:

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

If candidates are not to be disadvantaged it is important that every candidate can be linked, by the Examiner, to a particular Session/Laboratory and to a corresponding set of Supervisor's results. Regrettably a number of Centres continue to provide no, or incomplete, Supervisor information. Also, the Examiners would appreciate it if all Centres running more than one Session, and/or using more than one Laboratory, would instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

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

Some candidates were obviously very skilled in practical techniques, and hence scored well in questions needing accurate measurements or careful observations, whilst others showed good analytical skills in interpreting numerical or qualitative data.

It was evident that most candidates were familiar with the types of calculations included and the use of the Qualitative Analysis Notes so that they were able to obtain at least some credit in all three questions. There was little evidence of candidates not to finishing the paper in the allocated time as most completed all the questions.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work successfully, and most were able to gain credit in the early stages of the calculation. More able candidates showed their skill in moles based calculations by providing responses demonstrating clarity and elegance.

(a) The vast majority of candidates gave a value for the rough titre and burette readings for the accurate titres as instructed, and also diluted a volume of **FA 2** in the range given. However, there are still Centres whose candidates do not give burette readings to 0.05 cm^3. Some candidates appeared to squander time by carrying out a third accurate titration when the previous two were within 0.10 cm^3. These candidates ran the risk of the third titre not being concordant thus necessitating a fourth accurate titration.

(b) Most candidates selected appropriate titres for their mean. However, a few used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range. Candidates should ensure that the mean is calculated to an appropriate number of decimal places and is correctly rounded.

(c) In this section candidates were instructed to show working and quote answers to an appropriate number of significant figures. Credit could be gained for showing working, even if the actual numerical value was incorrect, and answers given to 3 or 4 significant figures were considered acceptable. Answers showing logical, clearly set out responses were able to achieve full credit.

(i) Most candidates calculated the concentration of hydrochloric acid in **FA 3** correctly.

(ii)(iii) Many used their titre from **(b)** and the mole ratio from the equation correctly.

(iv) Weaker candidates were less likely to gain credit here owing to confusion between hydrated and anhydrous sodium borate(III).

(v) It is important that candidates realise that credit can be gained if measured or calculated values are used logically even if the answer obtained is not realistic. However, the majority of candidates were able to complete the calculation.

(d)

(i) Almost all candidates calculated the maximum percentage error correctly for the volume pipetted into the conical flask.

(ii) Even though questions on percentage errors inherent in apparatus have appeared on previous papers, only a minority of candidates gained credit here as the majority did not double the single error when calculating the percentage error in the titre.

Question 2

Generally candidates performed well in the practical section of this question with many achieving maximum credit for accuracy. Credit for layout in this question encompassed the three practical sections and some candidates did not include all the data required in **(c)**. It is important for candidates to check their work to ensure that they carry out the instructions meticulously.

(a)(b) Almost all candidates gave the correct headings and units for their tables of results, and the balance readings showed a constant number of decimal places. However, when recording results of experiments using thermometers calibrated to 1 °C, candidates should ensure they quote all thermometer readings to the nearest 0.5 °C.

(c) The vast majority of candidates weighed the amount of **FA 6** in the range given. No further penalty was applied for those omitting the mass of bottle/tube + residue so credit for the calculation of the values of Δm and ΔT was available and was gained by most.

(d) Candidates are to be congratulated in that very few gave up when faced with a complicated-looking calculation. Many negotiated it successfully and had sufficiently good results to gain credit for the mass of sodium carbonate.

(e) Many of the answers did not give sufficient practical detail to be awarded credit. The most common correct responses were in terms of heating a known initial mass to constant mass or collecting and measuring the volume of gas evolved. However, some candidates choosing the latter incorrectly included water in their gas volumes.

Question 3

It was apparent that this question caused the candidates greater difficulty than the other two. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is not possible to answer such questions by rote as decisions have to be made as to the suitability of reagents and the likely outcomes of the tests using them. However, the majority of the candidates observed the instruction to give the correct full names or formulae for the reagents selected.

(a) The majority selected a named acid and recorded the expected observations for all three unknowns.

(b) While many candidates selected aqueous silver nitrate and ammonia as their first and second reagents respectively, a number chose aqueous lead nitrate as the second reagent. This would not be suitable as, assuming the results with silver nitrate were as expected, it would not give further information about the particular halide present.

(c) It is important that conclusions are backed up by relevant observations. The accepted descriptions of precipitates are to be found in the Qualitative Analysis Notes.

(d) Only a few candidates did not record the effect of adding excess reagent when a precipitate was seen. The observations for **FA 11** were generally fully correct but a substantial number did not report a white precipitate insoluble in excess aqueous ammonia with **FA 12**.

(e) This section was marked according to the observation recorded in **(d)**. Some candidates justified their choice of ion by writing about insoluble or soluble precipitates without mentioning the use of excess reagent. Others wrote that ‘it’ dissolved or did not dissolve in excess without clarifying what ‘it’ referred to.

(f) Candidates were expected to observe the blue/black coloration of the starch iodine complex in **(ii)** and also the formation of an appropriately coloured precipitate (of copper(I) iodide) in a brown solution, **(i)**, or the brown colour fading on the addition of aqueous sodium thiosulfate, **(iii)**. Not all observations were complete although most gained at least partial credit. There seemed to be some confusion about whether iodide or iodine had been formed and in which direction the redox lay. Many candidates clearly recognised that the formation of the blue/black coloration in **(ii)** was linked, in some way, with iodine. The least familiar species oxidised was the sulfur in the thiosulfate ion.

CHEMISTRY

Paper 9701/41
A2 Structured Questions

Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

General Comments

This paper provided candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry. 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.

Comments on Specific Questions

Question 1

(a) Candidates were generally aware of the triple bond in a nitrogen molecule, but not all went on to say that this was a *strong* bond or required considerable energy to break it.

(b) This calculation was completed only by the more able candidate, with others missing out terms. Even if all the terms were present, multipliers were often incorrect. The most common errors were omitting the bond energy of N_2 (or doubling it), using just the second ionisation energy of Mg, rather than the sum of the first two, and not multiplying the atomisation and ionisation energies by three. Candidates might have been more successful if they had drawn out the energy diagram for the process.

(c)

(i) Although this was a relatively easy equation, a large number of candidates thought that Li_2O was a product rather than LiOH.

(ii) Most candidates were able to give an advantage of the method, but fewer gave a reasonable disadvantage. Examiners were expecting candidates to think about the cost of lithium, the need to remove the LiOH, or its strongly basic nature.

(d)

(i) Most candidates carried out these calculations successfully.

(ii) A number of candidates gave amine rather than amide here.

(iii) Most candidates were able to give a correct equation.

(iv) Answers to this part were often too vague to be awarded credit. Some candidates referred to lithium metal or lithium nitride rather than lithium hydroxide in their answers.

Question 2

(a) This part was generally answered well, although a few candidates gave vague answers to one or both parts and could not be credited. The key point concerning a dynamic equilibrium is that the forward and reverse reactions are proceeding *at the same rate*.

(b)

(i) Most candidates gave a correct expression for K_c.

(ii) Although many candidates could give an expression for K_w, a smaller proportion could relate this to K_c, through the realisation that $[H_2O]$ was involved in the latter.

(iii) Only a fraction of candidates related the value of K_w to the fact that the reaction was endothermic.

(c) This question clearly divided candidates, with those who understood pH and were able to deal with calculations involving logs often receiving full credit, whilst those that were less confident receiving very little credit.

Question 3

(a) Candidates gave mixed answers here, with a surprising number omitting to state the oxidation numbers of the four elements. Even those who did do so often did not relate these to the number of outer/valency electrons lost.

(b) Many candidates did not answer the question here to <u>describe observations</u>. Examiners were expecting answers including the formation of misty fumes, the evolution of heat or some ‘fizzing’. There was also some uncertainty about the product of the reaction or writing a <u>balanced</u> equation. Acceptable products were H_3PO_4, HPO_3 and the partially hydrolysed $POCl_3$.

(c)

(i) Lots of candidates gained full credit here, although some unfortunately used a correct empirical formula of PCl_2 to get an incorrect molecular formula of P_3Cl_6.

(ii) A pleasing number of candidates were able to draw a correct structure. The most common error was to omit the lone pairs on the phosphorus atoms.

(iii) Most candidates correctly deduced that the oxidation number was +2.

(iv) This proved a trickier question with only more able candidates suggesting a correct structure, which could be obtained by replacing all four Cl atoms in P_2Cl_4 by OH groups.

Question 4

(a) All but the weakest candidates were able to write a correct equation here. Common errors were not balancing the equation or including a nitrogen atom rather than a nitrogen molecule.

(b)

(i) Most candidates knew that catalytic converters were used for this.

(ii) A significantly smaller proportion of candidates were able to write a balanced equation for the reaction which takes place in a catalytic converter.

(c) Although a good number of candidates were able to point out that nitrogen and oxygen were present in air and hence it was the temperature of combustion that was significant, many did not appreciate this point and thought that hydrogen would reduce the amount of NO_2 produced.

(d)

(i) Most candidates knew about ‘acid rain’, but a surprisingly large number did not link it to SO_3 when SO_2 would also be capable of producing an acid solution.

(ii) Only a small proportion of candidates did not write a correct equation.

(iii) A large number of candidates confused K_p with K_c here. Even those who gave the correct expression did not always state that the constant had no units.

(iv) Only the more able candidates evaluated this correctly. The most common error was not to square the (99.8/0.2) expression.

(v) As in question **2(b)(ii)** only a fraction of candidates realised that they needed to relate their answer to ΔH for the reaction.

Question 5

(a) This question caused problems for a significant number of candidates who seemed unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. The reactions of chlorine were poorly remembered, or guessed at, with chlorine sometimes absent as a reagent.

(b)

(i) Candidates are still unsure about drawing reaction mechanisms using ‘curly arrows’ and this was once again apparent in this question. Even those who were able to give a correct mechanism often did not write the equation for the formation of NO_2^+.

(ii) Most candidates correctly identified **C** as $C_6H_5CO_2H$.

(iii) Although stronger candidates knew the reagents and conditions for both steps, weaker candidates omitted one or both e.g. not mentioning the need for heat and acid/alkali with $KMnO_4$ or a ‘halogen carrier’ with Br_2.

Question 6

(a)

(i) A good number of candidates managed to identify the reagent and conditions.

(ii) Unfortunately not all of those who could give the reagent were able to write a structural formula *of a group* that would give a positive result. Either CH_3CO- or $CH_3CH(OH)$- was accepted, but complete compounds such as CH_3CHO or CH_3CH_2OH were not.

(iii) Most candidates were able to describe the results of a positive test.

(iv) As in question **5(a)** candidates often seemed unable to draw on knowledge from different areas of organic chemistry.

(b) There were a large number of poor drawings of structures here. Candidates must show the correct atoms bonded in the right sequence. Candidates had most difficulty with the structure of **D**, whilst often giving correct structures for **E** and **F**.

(c) In general, those candidates who scored well in **(a)(iv)** and **(b)** scored well here too. The most common error was to repeat structures for compounds **H**, **J** and **K**.

Question 7

It was pleasing to see that the whole of this question was generally well-answered making it one of the higher scoring questions on the paper.

(a) Weaker candidates did not relate the loss of enzyme activity to the structure and bonding in enzymes. Examiners were looking for answers which referred to the breaking of a specific type of bond in the tertiary structure of the enzyme.

(b) Most candidates were able to complete the diagrams although in a few cases impossible substrates were drawn.

(c) Some very good answers were given here suggesting that this area of the syllabus had been well-taught.

(d)

(i) Although most candidates drew a correct curve, a few clearly had little idea of the effect of non-competitive inhibitors.

(ii) This again proved difficult for some candidates who confused the effects of competitive and non-competitive inhibitors.

Question 8

(a) A surprisingly large number of candidates were unable to relate the two physical processes to their application in chromatography giving very vague answers which did not score. The key points were that in *partition*, components are separated due to their different solubilities, whereas in *adsorption*, the different attractions of the components to the stationary phase were important.

(b) This was well-answered by well-prepared candidates but a significant number of others seemed to guess at the answer.

(c)

(i) Many candidates recognised that the halogen was bromine, but a much smaller proportion referred to the near-identical heights of the M and M+2 peaks in the mass spectrum.

(ii) A pleasing proportion of the candidates used the M and M+1 peak heights to calculate the value of p correctly. Unfortunately not all of these followed the instructions given to calculate q.

(d) This part was less-well answered with a number of candidates giving ions or radicals rather than stable molecules or giving examples that had $\boldsymbol{M_r}$ equal to or greater than 30.

Question 9

(a) This was poorly answered with only about half the candidates receiving full credit. A significant number gave glycine as the monomer, disregarding the need for it to have one functional group.

(b) This was again poorly answered, even though Examiners accepted a range of possible valid answers. Some candidates merely repeated one difference stated the other way round. Examiners did not accept water if it was stated as *always* being produced in condensation polymerisation, but did so if it was given as an example of a small molecule eliminated in the process.

(c)

(i) Most candidates successfully gave water as the answer here.

(ii) A surprisingly low proportion of candidates gained full credit here. Most were able to show correctly the ester linkage, but a common error was to show oxygen links at both ends of the repeat unit.

(iii) Only about half the candidates correctly identified *Terylene* as a polyester, despite the hint given in the stem of the question.

(d) This question required a clear idea as to the difference between the process of addition polymerisation (involving monomers with identical C=C functional groups, although possibly having different side-chains), which can happen randomly; and that of condensation polymerisation, where the monomers had to join at their different functional groups in specific orientations. Only rarely did a candidate achieve full credit. Even those who correctly argued the random nature of the co-polymerisation of ethene and but-1-ene generally did not refer to *Terylene* needing alternating monomers in order to undergo condensation polymerisation.

CHEMISTRY

Paper 9701/42

A2 Structured Questions

Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

General comments

Although there was a large range of candidates' abilities, the overall standard seemed to be slightly higher than in previous years. There was very little evidence of candidates running out of time, and for the most part candidates wrote clearly and legibly. More able candidates were clearly stretched by some of the questions and there were some excellent answers to **Questions 1, 3** and **4** in particular. **Section B** also provided plenty of opportunities for candidates to demonstrate their knowledge and understanding of the applications and these questions were answered better than on some previous occasions.

Candidates should be reminded of the importance of a careful reading of the question before they attempt an answer. Thus **Question 1b(iii)** concerned itself *only* with the bonding in NH_4F, and not NH_3 or HF; **Question 1b(iv)** dealt with the *reverse*, not the forward reaction; **Question 5(a)** concerned the acidities of ethanol and phenol *relative to water*, not to each other; the *whole* of **Question 7(d)** was about archaeological investigations, so reference to forensics in **(ii)** was not relevant.

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

Comments on specific questions

Section A

Question 1

(a) This standard pH calculation was answered well by most candidates. Those not gaining full credit often divided K_a by 0.05 rather than multiplying, or forgot to take the square root before taking the log.

(b)

(i) Depending on how the candidate approached this question, several answers were considered correct, and given appropriate credit. These included acid-base, neutralisation, exothermic and reversible.

(ii) The 'dot-and-cross' diagram of the NH_3 molecule caused few problems, except the occasional lack of a lone pair on N. Several candidates drew an ionic structure for HF, rather than the desired covalent one. The structure of NH_4F caused the most problems. The dative bond needed to be shown with two identical electrons within it and the fluoride ion needed to have four electron pairs shown around it of which one had to contain an F electron and an H electron.

(iii) Quite a number of candidates described the bonding in NH_3 and/or HF, rather than restricting their answer to NH_4F, as the question required. A significant number of candidates thought that hydrogen bonding was involved, either in HF or in NH_4F.

(iv) Most candidates recognised that the reverse reaction was endothermic, and so would be favoured by high temperature. Many also predicted that a decrease in pressure would favour the reverse process, but few stated explicitly that this was due to there being two moles *of gas* formed during the reverse reaction.

(c)

(i) This equation was given correctly by most candidates.

(ii) Most candidates also knew that the cuprammonium ion is *deep blue* or *purple*.

(iii) It was clear that quite a number of candidates had not seen this dilution carried out. They either predicted that the colour would merely fade due to dilution, or that no change would be seen. In fact, there is a distinct change in colour, from a deep, purple-like blue to a lighter, purer blue. The partial replacement of NH_3 ligand by H_2O ligands, giving the mixed complex $[Cu(NH_3)_n(H_2O)_{6-n}]^{2+}$ (where n < 4 or even n = 0) was correctly described by many candidates.

(d) Several candidates thought this was either a redox reaction, or an acid-base reaction. Ligand exchange or ligand replacement, were acceptable answers. The formula of the product was accepted as $[CuCl_4]^{2-}$ or $[Cu(H_2O)_{6-n}Cl_n]^{2-n}$, and the balanced equation needed to start with $[Cu(H_2O)_6]^{2+}$.

Question 2

(a)

(i) The more structured way of asking this question helped candidates show their knowledge of these Group IV trends. Most knew that the melting points decreased from C to Si-Ge to Sn-Pb. The conductivity of carbon was accepted to be either ‘high’ (for graphite) or ‘low’ (for diamond).

(ii) The key points here were that down Group IV the melting points decreased due to the change from *giant molecular* to *metallic bonding* and the conductivity increased due to the increasing number of *delocalised electrons*.

(b)

(i)(ii) The best reaction to illustrate the relative stabilities of PbO_2 and PbO is the production of PbO by the action of heat on PbO_2. Likewise, the burning of CO in air to produce CO_2 shows the relative stabilities of the two carbon oxides. Most candidates chose these reactions, and wrote correct balanced equations, but some forgot to mention that in the first case the PbO_2 had to be heated, and in the second case the CO burned with a blue flame.

(iii) There were many reactants that candidates could have chosen to illustrate the reducing power of $SnCl_2$. Those given credit included MnO_4^-, $Cr_2O_7^{2-}$, Fe^{3+}, Cu^{2+}, Ag^+, and the halogens. Many candidates scored well for the balanced equation, but some did not mention the colour changes involved.

Question 3

(a) Most candidates scored credit here. Either $L = F/e$ or $F = Le$ were accepted. Those candidates who merely showed a proportionality relationship (e.g. $F \propto Le$) were not given credit.

(b)

(i) Most candidates drew a correct diagram, including a power pack (with the + and – terminals labelled), an ammeter in series, a beaker with two electrodes (correctly labelled as cathode and anode) dipping into aqueous $CuSO_4$. However, a significant number of candidates incorrectly drew the two-beaker-with-salt-bridge circuit, used to measure electrode potentials.

(ii) Many candidates were able to calculate the number of moles of copper (=4.71×10^{-3} mol); the number of moles of electrons needed to deposit the copper (=9.42×10^{-3} mol, due to Cu being divalent); and the amount of electricity passed (=900 C). But then some went on to use just the *Data Booklet* values of F and e to calculate L, rather than completing their own calculation. Although the final figure needed to be quoted to three significant figures, in order to get the right answer, candidates had to keep 4 or more significant figures in their intermediate answers.

(c) Some candidates confused anode and cathode, but many scored well here. According to $E^{\ominus}$ values, oxygen would be liberated at the anode of every solution except $MgBr_2$, and hydrogen would be evolved at the cathode of every solution except AgF. Some candidates incorrectly gave the formulae of the ions that would undergo electrode reactions, rather than the products of those reactions.

Question 4

(a)

(i) The presence of the ester group in **B** confused many candidates, who tried to write PVA as a polyester. PVA is an addition polymer (similar to PVC), whose chain is a linear backbone of $–CH_2–CH(OCOCH_3)–$ units.

(ii) Only the more able candidates recognised that **C** should have been ethenyl alcohol, $CH_2=CH–OH$.

(iii) Candidates fared better with this part, with the majority drawing the structure of ethanal, $CH_3CH=O$.

(iv) A correct confirmatory test was also chosen by the majority of candidates. 2,4-DNPH or Fehling’s solution were the favourites. A common error was to repeat the iodoform test, which had already been described in the question.

(b)

(i) Any three consecutive atoms along the chain, with their attached groups or atoms, would have gained credit here. Quite a number of candidates incorrectly chose a 6-atom chain as the repeat unit (i.e. double the correct unit). They were not unfairly penalised again for this further in the question.

(ii) The correct answer, ester, was given by the majority of candidates. Ketone, carbonyl or carboxyl were the most common incorrect answers.

(iii) Candidates found this part remarkably difficult. Several drew ring structures; others drew repeat units rather than the monomer. This could have been either 2-hydroxybutanoic acid or its acyl chloride.

(iv) Candidates had little problem in identifying **D** as a condensation polymer.

(v) Several answers were accepted here. If the two repeat units had been correctly identified, then “isomers” or “the same molecular formula” would have been appropriate. Otherwise, “ester” or “same functional group” were accepted.

(c)

(i) **E** shows optical stereoisomerism. Despite having written an acceptable structure for **E** quite a number of candidates did not recognise this type of isomerism.

(ii) Only a minority of candidates identified **F** and **G** as the cis- and trans- isomers of but-2-eneoic acid.

Question 5

(a) Whilst the majority of candidates knew that ethanol was less acidic than phenol, many did not relate the acidities of the two organic hydroxy-compounds to that of water, as the question required. The explanations, in terms of the positive inductive effect of the ethyl group in ethanol, and the stabilisation of the phenoxide anion by charge delocalisation for phenol, were described well by some candidates.

(b) Whilst most candidates recognised sodium phenoxide as the product of the first two reactions, many left out the other products – hydrogen and water respectively. Some thought the product of the first reaction was H^+ rather than H_2. A large number of candidates thought, incorrectly, that the third reaction would produce phenyl ethanoate – phenol does not undergo the usual esterification with carboxylic acids. Although most gained credit for tribromophenol being the product of the fourth reaction, fewer correctly identified the conditions as being in aqueous solution (in the absence of light or Lewis acid catalyst).

(c) Most candidates correctly identified **H** as 4-nitrophenol, although a great many suggested HNO_3 *and* H_2SO_4 as the reagent, rather than *dilute* HNO_3. Most gained credit for Sn + HCl for step 2, and also a mark for CH_3COCl for step 3.

Section B

Question 6

(a) Hydrophilic, polar, hydrogen-bonding, ionic – any of these would have received credit here, and most candidates knew at least one of them.

(b)

(i) For the primary structure, most candidates described it as being a series of amino acids, but few realised that it is the *sequence* of amino acids that is important. The secondary structure had to be described as being due to hydrogen bonding *between the peptide groups*, as distinct from hydrogen bonding between side chains, which is involved in the tertiary structure. Almost all candidates gained credit for describing the tertiary structure as being due to interactions between side chains resulting in the overall 3-D structure.

(ii) The key point here was that the tertiary structure provides a complementary shape to that of the substrate.

(iii) Most candidates chose two out of high temperature, change in pH or presence of inhibitors as the conditions, with explanations in terms of changes in the tertiary structure or the inhibitor occupying the active site.

(c)

(i) Most candidates performed well here.

(ii) A peak centred on pH 7 and labelled amylase, was required. Some candidates did not label the peak, whilst other centred it at pH 5 to 5.5, mid-way between the other two.

Question 7

(a) Most candidates appreciated that the production of genetic fingerprinting starts with the extraction of DNA, followed by the use of restriction enzymes before using the polymerase chain reaction. There were different opinions as to when the samples were labelled with radioactive isotopes – some suggested it was before electrophoresis (before or after placing on the agarose gel), and some suggested, correctly, that it was after the electrophoresis had been completed.

(b)

(i) Many different elements were suggested here: helium, carbon, nitrogen, iodine, uranium and polonium. The correct isotope, ^{32}P, was known by a good number of candidates.

(ii) Two types of reason were accepted for why ^{32}P was used: either that DNA contains phosphate groups, so the ^{32}P could easily be incorporated or that the presence of a radioactive isotope allowed the identification of the positions of the bands on the photographic plate. Several candidates thought, incorrectly, that it made the spots coloured.

(c)

(i) Most candidates correctly stated that all the children were related to the mother, but some gave as evidence the general statement “their fingerprints match the mother’s”, which is incorrect. They needed to state that at least *one band* of each child’s fingerprint matched the mother’s.

(ii) Since *none* of the bands of child 2 matched those of the father, the general term “their fingerprints do not match” was acceptable here.

(d)

(i) Some candidates misunderstood the question, and thought that the DNA in the skin fragments had to be compared to the DNA of a *modern* goat. The general principle was understood by most candidates however – that each fragment’s fingerprint had to be taken, and those fingerprints compared to each other, to see which were the same, and hence originated from the same skin.

(ii) The material had to be of archaeological origin, as stated in the stem of **(d)**, so references to modern-day forensics were ignored. Acceptable answers included leather, fish scales, pollen, seeds, feathers, hair etc.

Question 8

(a) Because of the use of negative indices, some candidates confused “upper” and “lower”. Even allowing for this, however, there were very few candidates who scored full credit here. The acceptable ranges were between 10^{-6} and 10^{-7} for the upper limit, and between 10^{-8} and 10^{-9} for the lower limit. There were many answers in the 10^{-9} to 10^{-12} range.

(b) Most candidates recognised that allotropes contain atoms of the *same element*, and many also stated that they had different structures, or differed in the arrangements of their atoms.

(c) In general, candidates knew that nanoparticles can enclose drug molecules within their ‘cage’, but fewer described the ability of the small nanoparticle to pass through cell membranes and enter cells.

(d)

(i) *Reduction* or *redox* were acceptable answers. The most common incorrect answers were *oxidation* and *electrolysis*.

(ii) Although some candidates gave 25% as the answer (i.e. one quarter of the atoms in $CuFeS_2$ are copper), most were able to calculate the correct value of 34.6%.

(iii) In this part also, most candidates scored full credit, for 6.9 kg.

(iv) Some candidates suggested that Fe^{2+} could reduce Cu^{2+} to Cu(s), despite the $E^\ominus$ value for Fe^{3+}/Fe^{2+} being more positive than that for Cu^{2+}/Cu. Suitable metal reductants could be Fe (the most popular), Zn, Pb, Sn, A*l* and Mg (Ca, Na and K would be *too* reactive, reacting with water instead). Alternatively, electrolysis was accepted as a recovery method.

CHEMISTRY

Paper 9701/43
A2 Structured Questions

Key messages

- Many candidates would benefit from an increased familiarity with skeletal formulae.
- Many candidates were still unsure about drawing reaction mechanisms using 'curly arrows'. Increased practice of using curly arrow notation would be beneficial to many candidates.
- Candidates should be reminded that numeric answers should be given to an appropriate number of significant figures.

General comments

Although there was a large range of candidates' abilities, the overall standard seemed to be slightly higher than in previous years. There was very little evidence of candidates running out of time, and for the most part candidates wrote clearly and legibly. More able candidates were clearly stretched by some of the questions and there were some excellent answers to **Questions 1, 3** and **4** in particular. **Section B** also provided plenty of opportunities for candidates to demonstrate their knowledge and understanding of the applications and these questions were answered better than on some previous occasions.

Candidates should be reminded of the importance of a careful reading of the question before they attempt an answer. Thus **Question 1b(iii)** concerned itself *only* with the bonding in NH_4F, and not NH_3 or HF; **Question 1b(iv)** dealt with the *reverse*, not the forward reaction; **Question 5(a)** concerned the acidities of ethanol and phenol *relative to water*, not to each other; the *whole* of **Question 7(d)** was about archaeological investigations, so reference to forensics in **(ii)** was not relevant.

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

Comments on specific questions

Section A

Question 1

(a) This standard pH calculation was answered well by most candidates. Those not gaining full credit often divided K_a by 0.05 rather than multiplying, or forgot to take the square root before taking the log.

(b)

(i) Depending on how the candidate approached this question, several answers were considered correct, and given appropriate credit. These included acid-base, neutralisation, exothermic and reversible.

(ii) The 'dot-and-cross' diagram of the NH_3 molecule caused few problems, except the occasional lack of a lone pair on N. Several candidates drew an ionic structure for HF, rather than the desired covalent one. The structure of NH_4F caused the most problems. The dative bond needed to be shown with two identical electrons within it and the fluoride ion needed to have four electron pairs shown around it of which one had to contain an F electron and an H electron.

(iii) Quite a number of candidates described the bonding in NH_3 and/or HF, rather than restricting their answer to NH_4F, as the question required. A significant number of candidates thought that hydrogen bonding was involved, either in HF or in NH_4F.

(iv) Most candidates recognised that the reverse reaction was endothermic, and so would be favoured by high temperature. Many also predicted that a decrease in pressure would favour the reverse process, but few stated explicitly that this was due to there being two moles *of gas* formed during the reverse reaction.

(c)

(i) This equation was given correctly by most candidates.

(ii) Most candidates also knew that the cuprammonium ion is *deep blue* or *purple*.

(iii) It was clear that quite a number of candidates had not seen this dilution carried out. They either predicted that the colour would merely fade due to dilution, or that no change would be seen. In fact, there is a distinct change in colour, from a deep, purple-like blue to a lighter, purer blue. The partial replacement of NH_3 ligand by H_2O ligands, giving the mixed complex $[Cu(NH_3)_n(H_2O)_{6-n}]^{2+}$ (where n < 4 or even n = 0) was correctly described by many candidates.

(d) Several candidates thought this was either a redox reaction, or an acid-base reaction. Ligand exchange or ligand replacement, were acceptable answers. The formula of the product was accepted as $[CuCl_4]^{2-}$ or $[Cu(H_2O)_{6-n}Cl_n]^{2-n}$, and the balanced equation needed to start with $[Cu(H_2O)_6]^{2+}$.

Question 2

(a)

(i) The more structured way of asking this question helped candidates show their knowledge of these Group IV trends. Most knew that the melting points decreased from C to Si-Ge to Sn-Pb. The conductivity of carbon was accepted to be either ‘high’ (for graphite) or ‘low’ (for diamond).

(ii) The key points here were that down Group IV the melting points decreased due to the change from *giant molecular* to *metallic bonding* and the conductivity increased due to the increasing number of *delocalised electrons*.

(b)

(i)(ii) The best reaction to illustrate the relative stabilities of PbO_2 and PbO is the production of PbO by the action of heat on PbO_2. Likewise, the burning of CO in air to produce CO_2 shows the relative stabilities of the two carbon oxides. Most candidates chose these reactions, and wrote correct balanced equations, but some forgot to mention that in the first case the PbO_2 had to be heated, and in the second case the CO burned with a blue flame.

(iii) There were many reactants that candidates could have chosen to illustrate the reducing power of $SnCl_2$. Those given credit included MnO_4^-, $Cr_2O_7^{2-}$, Fe^{3+}, Cu^{2+}, Ag^+, and the halogens. Many candidates scored well for the balanced equation, but some did not mention the colour changes involved.

Question 3

(a) Most candidates scored credit here. Either $L = F/e$ or $F = Le$ were accepted. Those candidates who merely showed a proportionality relationship (e.g. $F \propto Le$) were not given credit.

(b)

(i) Most candidates drew a correct diagram, including a power pack (with the + and – terminals labelled), an ammeter in series, a beaker with two electrodes (correctly labelled as cathode and anode) dipping into aqueous $CuSO_4$. However, a significant number of candidates incorrectly drew the two-beaker-with-salt-bridge circuit, used to measure electrode potentials.

(ii) Many candidates were able to calculate the number of moles of copper (=4.71×10^{-3} mol); the number of moles of electrons needed to deposit the copper (=9.42×10^{-3} mol, due to Cu being divalent); and the amount of electricity passed (=900 C). But then some went on to use just the *Data Booklet* values of F and e to calculate L, rather than completing their own calculation. Although the final figure needed to be quoted to three significant figures, in order to get the right answer, candidates had to keep 4 or more significant figures in their intermediate answers.

(c) Some candidates confused anode and cathode, but many scored well here. According to $E^{\ominus}$ values, oxygen would be liberated at the anode of every solution except $MgBr_2$, and hydrogen would be evolved at the cathode of every solution except AgF. Some candidates incorrectly gave the formulae of the ions that would undergo electrode reactions, rather than the products of those reactions.

Question 4

(a)

(i) The presence of the ester group in **B** confused many candidates, who tried to write PVA as a polyester. PVA is an addition polymer (similar to PVC), whose chain is a linear backbone of $–CH_2–CH(OCOCH_3)–$ units.

(ii) Only the more able candidates recognised that **C** should have been ethenyl alcohol, $CH_2{=}CH–OH$.

(iii) Candidates fared better with this part, with the majority drawing the structure of ethanal, $CH_3CH{=}O$.

(iv) A correct confirmatory test was also chosen by the majority of candidates. 2,4-DNPH or Fehling's solution were the favourites. A common error was to repeat the iodoform test, which had already been described in the question.

(b)

(i) Any three consecutive atoms along the chain, with their attached groups or atoms, would have gained credit here. Quite a number of candidates incorrectly chose a 6-atom chain as the repeat unit (i.e. double the correct unit). They were not unfairly penalised again for this further in the question.

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CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- As always, candidates should be encouraged to read each question carefully before answering.
- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.
- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

General comments

In **Question 1** the stem of the question provided three prompts to responses to include in the answer. Candidates should be made aware that the examination answers require these points to be addressed.

In **Question 2**, two points about data tables are common every session. Firstly, candidates need to label each new column used. These labels require three items – a written label, a correct unit and an expression to be used to calculate the column data. All of these items are required for credit to be awarded (often the expression is omitted). Secondly, the data needs to be correctly quoted to either a specified number of decimal places or significant figures. In this examination, the data requirement was for 2 significant figures in moles. Candidates should be advised to look for the required significance/decimal places before calculating any data.

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

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

Comments on specific questions

Question 1

(a)

(i) Most candidates correctly predicted a decrease in rate of reaction as charge density decreases. This required a good understanding of charge density or careful reading of the stem of the question which guided the candidates to a good answer. The most common deviation was that the rate would increase. Some candidates restated the information given in the stem of the question. The explanation of the prediction required a relation between charge density and distortion or polarisation, as required by the question. A link between these two was essential. A number of candidates restated the prediction (albeit in different words).

(ii) The requirement of the sketch graph was to graphically illustrate the prediction made earlier. Thus rate (of decomposition) was required as one of the axes. This was often not present. The commonest alternatives of time or volume of CO_2 did not address the question. There were a number of acceptable alternatives for the other axis but many who used charge density often sketched the inverse relationship.

(b) The two variables were often named well. While most candidates seemed to realise the difference between independent and dependent variables, it appears that a significant minority had them inverted. The dependent variable ('which carbonate', or words to that effect) was sometimes negatively linked with its mass. Multiple answers to a single question which carries a single mark are open to error where such a list can contain an incorrect response that negates a correct one. Thus list responses are to be avoided.

(c) Most candidates attempted a diagram and, whilst the variation in the quality of the diagrams was large, most scored at least partial credit. The container of the carbonate needed to be not open to the air and capable of being heated strongly (not by means of a water bath). There were some impractical solutions such as an evaporating basin with a funnel on top. The collection device (gas syringe, measuring cylinder over water etc.) needed to have a stated capacity and be calibrated. Some collectors had unreasonable capacities notably many cubic decimetres or 1 cm^3.

(d) Only a small number of candidates performed well in this part. The stem of the question in asking for a description required the candidates to respond to three distinct prompts. Many of the candidates did not respond to these prompts. Most commonly candidates described weighing the carbonates and setting up the apparatus at some length, neither of which gained any credit. The first prompt was for a stated volume of carbon dioxide that would fit the collector. Many candidates did not receive credit here, settling for the production of the same volume instead. The second prompt of carbonate mass required a realisation that only the same number of moles of each carbonate would produce the same volume of carbon dioxide. This would therefore require a different mass of each carbonate. In some calculations, candidates confused dm^3 with cm^3. Many candidates proposed that the same mass of each carbonate was required. In the third prompt very few candidates realised how to control the heating in terms of settings on the heating device and its position with regard to the reaction vessel. Most had no response to this point and many had vague responses in terms of using insulation or controlling room temperature. Although the question on page 2 states "finding the time taken to produce the same volume of carbon dioxide from each carbonate", many candidates described a different scenario of finding the volume (or even mass) of carbon dioxide in a set time.

(e) The only realistic hazard here was hot pieces of apparatus. There were many unrealistic attempts at hazards which included carbon dioxide toxicity, metal oxides being corrosive, breaking glass and tubes exploding under pressure.

(f) Most candidates scored at least partial credit here. The requirement was for three columns, one headed carbonate (with four rows), one time and the third rate. The commonest omission was the rate column and unnecessary columns were common. Care needs to be taken with units (sec is not acceptable for seconds, only s). CIE require that units in table headings are given as /s or (s).

(g) Very few gained any credit here. The question required a change to the apparatus such as a more controllable device. Many suggested lagging or shielding from draughts.

Question 2

(a) Most candidates calculated the M_rs of the two compounds correctly.

(b) Candidates should be encouraged to read the text around the table before completing it. There are two common errors in headings and data that occur regularly.

Each column heading needs three things, a description (e.g. mass of $NaNO_3$), a unit (e.g. /g) and an expression to calculate the data (e.g. B-A) as required.

Also stated is a requirement for a specific number of significant figures or decimal places. There is a general misunderstanding of the difference between significant figures, decimal places and trailing zeros. In this case the requirement was for 2 decimal places in mass and 2 significant figures in moles. There was a frequent misunderstanding of this requirement particularly in significant figures in moles. For example, 0.038 (2 sig figs.) was given as 0.04 (2 decimal places), even to the extent of seeing 0.038 written but crossed out and replaced by 0.04 where, presumably, the candidate believes 2 decimal places is the same as 2 significant figures. Also a calculated value of 3.2 needs to reported as 3.20 if 2 decimal places are required. Care needs to be taken with the reporting of data.

(c) Two factors need to be considered in graph work. Firstly it is the independent variable that is to be plotted on the *x*-axis and the dependent on the *y*-axis. In this situation the independent variable was moles of sodium nitrate and the data/relationships should always be examined to see if the origin (0,0) is a valid point. If so (as in this question) then the scaling used could include the origin and any line drawn would include the origin since it would be a definite point not subject to any experimental error as the other points may be. In most cases candidates did not include a true origin but most chose reasonable scales that facilitated plotting. Even so some candidates chose difficult scales which made plotting difficult without using a calculator for each point. An example of difficult scaling is 0.01 being scaled at 8 small squares (1 small square = 0.00125. This creates difficulties for the candidate in correctly plotting data of the nature of 0.038 so mis-plotting is often seen when such inconvenient scales are chosen. Some candidates chose a scale for the nitrate moles that did not accommodate all the points giving the last point(s) outside the grid. The scaling chosen must adequately cover the available grid but the minimum requirement is for the plot to cover at least half of the grid in both directions. So the candidates must make a compromise between scaling and grid coverage to use at least half of the grid in both directions with a reasonable scale that can be easily used. If the true origin is used correctly it can be classed as a point in assessing if half the grid has been used.

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

Very few candidates plotted values other than the two mole quantities.

(d) Most candidates could identify two anomalies, one on each side of the line. Some candidates who had over-rounded data to 2 decimal places or had arithmetic errors in the table or mis-plots inevitably had different/more anomalies. Anomalies were mostly correctly identified but some candidates did not mark all of the anomalies that were present.

The descriptions of causes for anomalies needed to be more carefully done. For the most part the anomalous points being described were unambiguously identified e.g. experiment 4 (or 0.034, 0.041) and a circle written on the graph. Often the reason given for the anomaly was a restatement of its position in the plot, thus "Point 4 is anomalous as moles of nitrite are too high" would not gain credit. It was necessary to give the cause such as incomplete decomposition for experiment 4. Many candidates had the reasons inverted around experiments 4 and 7.

(e) Most candidates drew construction lines. The co-ordinates of a table point may be used provided they lie on the line and the construction lines are drawn to them. If plotted, the origin is a good point to use. If not, it cannot be assumed. The nature of the data made the calculation of the slope straightforward and most had 1. Some had slopes of 0.96 etc. which were usually properly corrected to 1. Some candidates had the *x,y* values inverted and some calculated negative values in the slope expression e.g. 0.04 – 0.09 = 0.05.

(f)

(i) Most candidates gained credit here.

(ii) To gain credit, the candidate needed to state the equality between the slope and the molar ratio from the equation. Whist many candidates succeeded here, others just quoted one value or the other.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- As always, candidates should be encouraged to read each question carefully before answering.
- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.
- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

General comments

Overall, although the paper once again proved to be quite challenging many of the questions produced good answers. Again, however some of the part questions only occasionally produced a correct response. Candidates sometimes did not appreciate the precision of answer required by some of the questions and there was evidence of candidate unfamiliarity with some of the concepts involved. In particular, planning skills were again often limited with candidates finding it difficult to provide the specific detail required. An enhanced familiarity with experimental techniques would be of benefit to all candidates. Candidates need to appreciate that in drawing a ‘line of best fit’ both straight-lines or curves are possible.

Comments on specific questions

Question 1

(a) Most candidates gained credit in **(i)**, although the explanation sometimes did not highlight the key point that it is the rate of collision which increases with the temperature. Correct alternatives such as an increased energy of collision were also offered. Most candidates produced a sketch graph showing the increase in rate with temperature in **(ii)** although a significant number of candidates incorrectly used time rather than rate.

(b) The temperature was generally seen as the independent variable with the time or rate identified as the dependent variable. Occasionally these were reversed.

(c) Credit for the diagram was regularly accessed by showing a simple apparatus, such as a beaker, containing a ‘liquid’ with some form of heating and a thermometer immersed in the liquid. This liquid would equate to the reaction mixture. Some candidates included the use of a water bath with the thermometer immersed in it, a quite acceptable alternative.

For further credit to be awarded, both the volume of the reaction vessel and a thermometer with a numerical range which would allow the experiments detailed in **(d)** to be carried out, were required. It was also required to specify both the minimum and the maximum temperature for the thermometer. This was often not seen.

(d) A clear indication of a minimum of five experiments gained credit while further credit was awarded if the experiments covered a range of at least 25 °C. Some of the candidates erroneously interpreted the concept of a range as referring to a range for each experiment rather than a range covering all the experiments. Candidates were required to indicate clearly that the volumes of the two reagents should remain constant throughout all the experiments. These first few marking points were generally achieved but candidates had greater difficulty with the remainder of the question. Candidates needed to be clear that either the temperatures of both reagents were measured immediately prior to mixing or immediately on mixing, either format requiring that the timing start synchronously. Many candidates only measured the temperature of one of the reagents while others started the reaction prior to heating the mixture to a starting temperature, only then starting the timing. It was not always clear how the appearance of the opacity was judged.

(e) One hazard in this exercise was the hot apparatus, an appropriate remedy being the use of thermal gloves. An acceptable alternative was the use of gloves and goggles to combat problems with the hydrochloric acid. A common error was a reference to the Bunsen burner.

(f) There was a minimum of three column headings required to gain the full credit available; the temperature, the elapsed time and the rate of reaction (all three of these requiring an indication of the correct units). Additional columns were ignored. Credit for **(d)** could often be awarded in this section.

Question 2

(a) The calculations of the masses of the water and the solid were generally correct with the correct expressions; the calculation of the solubility was less well derived.

The correct expression was often omitted or lacked the 100 factor and the two significant figures requirement was often seemingly interpreted as two decimal places.

(b) The quality of most of the graphical work was generally high with the most common error being the shape of the graph. On this occasion the points, when correctly interpreted, gave a smooth curve however many seemed to interpret the instruction to draw a line of best fit as being a straight-line; this having been the correct interpretation on some recent papers. Some candidates reversed the axes. Many candidates chose sensible scales making the confirmation of accuracy straightforward with the plotting showing a comfortable degree of accuracy in most cases. If the plotting was accurate, two anomalous points were revealed but those drawing a straight-line saw rather more than two anomalies.

(c) Most candidates were able to identify correctly the two anomalous points, although credit was given for any number of points not clearly on the drawn line that were correctly identified. Correct explanations of the anomalies were quite infrequent with many answers referring erroneously to mass differences or spillage of some sort. Correct answers should have focused on whether the temperatures were read early or late or possible evaporation of the water during heating.

(d) To receive credit here candidates needed to determine the difference between the two solubility readings from the graph as drawn at 85 °C and 35 °C and then divide by two. Many candidates found this difficult, a common error being to take the solubility at 50 °C. It seemed possible that many candidates were unable to interpret correctly the solubility curve.

(e) This section was generally answered well with many candidates scoring full credit. Some of the explanations were rather confused with erroneous offerings involving irrelevant concepts.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- As always, candidates should be encouraged to read each question carefully before answering.
- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.
- Candidates should be reminded that answers should be given to an appropriate degree of accuracy.

General comments

Overall, although the paper once again proved to be quite challenging many of the questions produced good answers. Again, however some of the part questions only occasionally produced a correct response. Candidates sometimes did not appreciate the precision of answer required by some of the questions and there was evidence of candidate unfamiliarity with some of the concepts involved. In particular, planning skills were again often limited with candidates finding it difficult to provide the specific detail required. An enhanced familiarity with experimental techniques would be of benefit to all candidates. Candidates need to appreciate that in drawing a ‘line of best fit’ both straight-lines or curves are possible.

Comments on specific questions

Question 1

(a) Most candidates gained credit in **(i)**, although the explanation sometimes did not highlight the key point that it is the rate of collision which increases with the temperature. Correct alternatives such as an increased energy of collision were also offered. Most candidates produced a sketch graph showing the increase in rate with temperature in **(ii)** although a significant number of candidates incorrectly used time rather than rate.

(b) The temperature was generally seen as the independent variable with the time or rate identified as the dependent variable. Occasionally these were reversed.

(c) Credit for the diagram was regularly accessed by showing a simple apparatus, such as a beaker, containing a ‘liquid’ with some form of heating and a thermometer immersed in the liquid. This liquid would equate to the reaction mixture. Some candidates included the use of a water bath with the thermometer immersed in it, a quite acceptable alternative.

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