CHEMISTRY

Paper 9701/11
Multiple Choice

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

This examination paper provided a difficult challenge to the candidates. There were some pleasing performances, but very few really good ones. A very few candidates achieved excellent scores.

Seventeen questions can be said to have been found to be easier. These were **Questions 3**, **4**, **5**, **6**, **8**, **10**, **11**, **12**, **15**, **16**, **17**, **20**, **25**, **26**, **29**, **37** and **39**. **Questions 39** and **40** were both answered correctly by a significant number of candidates, suggesting that most candidates found they had sufficient time to complete the paper properly.

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

Question 2: The correct answer was **D**. The most commonly chosen incorrect answer was **C**. The key word in this question is **not**, which was in bold type. The use of bold type in a question is always significant. Choices **A**, **B**, and **C** will all increase the rate of the forward reaction used in the Haber Process. Removing the ammonia as it is formed will result in a decrease in concentration of nitrogen and hydrogen, since it will stop the backward reaction, so this will **not** increase the rate of the forward reaction.

Question 18: The correct answer was **C**. The most commonly chosen incorrect answers were **B** and **D**. The relevant product of the first reaction (conc H_2SO_4 + KCl) is HCl. HCl will not react with KI(aq), so observation X is "colourless solution". The second reaction was between KCl and $AgNO_3$ in the presence of ammonia solution. The expected product, $AgCl$, is soluble in ammonia solution, so observation Y is also "colourless solution".

Question 32: The correct answer was **B**. The most commonly chosen incorrect answer was **D**. This suggests that most candidates appreciated that O and Cl^+ both have four p electrons, therefore providing one answer to the question. However, many candidates then failed to appreciate that F^+ with four p electrons has two unpaired p electrons, the same number as are present in Ga^-. Choices **1** and **2** are both correct.

Question 36: The correct answer was **A**. The most commonly chosen incorrect answer was **B**. This suggests that for many candidates their choice of answer rested on the truth or otherwise of choice **3**. If the operating pressure is increased for a process in which all reactants and products are gases then **both** the rate of the forward reaction and the rate of the backward reaction will increase, although by different amounts.

Question 38: The correct answer was **A**. Approximately equal numbers of candidates chose **B**, **C** and **D**, the remainder of candidates either failing to answer or entering an invalid response, e.g. selecting two or more options. This suggests that a substantial number of candidates may have guessed this question. Candidates first had to satisfy themselves that isomers of $C_4H_{10}O$ exist that can be oxidised to give the three named products. Then they had to calculate that 70 g of $C_4H_{10}O$ is 0.946 moles and calculate that 62% of this is 0.586 moles of product. Finally they had to confirm that 0.586 moles of each named product does have the stated mass.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There were many pleasing performances, as well as some really good ones. A number of candidates scored full credit.

Thirteen questions can be said to have been found to be easier. These were **Questions 1**, **2**, **8**, **9**, **11**, **12**, **14**, **15**, **18**, **19**, **21**, **39** and **40**. **Questions 39** and **40** were each answered correctly by the vast majority of candidates, suggesting that most candidates found they had sufficient time to complete the paper properly.

Four questions can be said to have been found to be particularly difficult. These were **Questions 13**, **24**, **28** and **34**.

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

Question 13: The correct answer was **C**. The most commonly chosen incorrect answers were **A** and **B**. Air is approximately 80% nitrogen, very little of which reacts in the engine, therefore nitrogen will be present in the greatest amount in the exhaust fumes. A hypothetical equation such as:

$$CH_2 + 1\frac{1}{2}O_2 + 6N_2 \rightarrow CO_2 + H_2O + 6N_2$$

confirms this. In this hypothetical equation CH_2 has been used as the approximate empirical formula of a hydrocarbon fuel. $6N_2$ are included as this is the number of nitrogen molecules taken into the engine along with "$1\frac{1}{2}O_2$" due to air being approximately 20% oxygen and 80% nitrogen.

Question 24: The correct answer was **A**. The most commonly chosen incorrect answer was **B**. This suggests that many of the candidates' decisions rested on whether or not $CH_2{=}CHCH{=}CH_2$ can be formed. This compound can be formed in the reaction $CH_3(CH_2)_5CH{=}CH_2 \rightarrow CH_3(CH_2)_2CH_3 + CH_2{=}CHCH{=}CH_2$ hence the answer **A**.

Question 28: The correct answer was **D**. The most commonly chosen incorrect answers were **A** and **B**. These answers, **A** and **B**, both have compound **X** having a cyclopentane ring which would have to be opened by the reaction with ammonia. This will not occur. Compound **X** must be 1,5-dibromooctane. The reaction of 1,5-dibromooctane with ammonia takes place by nucleophilic substitution in two steps. In the first step of the reaction an $–NH_2$ group substitutes for one of the bromine atoms. Since this $–NH_2$ group has a lone pair it can attack the $\delta+$ carbon atom of the second C-Br by the same nucleophilic mechanism, giving coniine as the organic product.

Question 34: The correct answer was **B**. A number of candidates chose **A**, **C**, and **D**, suggesting that a significant number may have guessed their response. A few candidates either gave no answer or gave an invalid answer to this question. In Syllabus Section 9.4*(f)(i)* candidates are required to "describe and explain the reactions of halide ions with aqueous silver ions followed by aqueous ammonia". When silver chloride dissolves in aqueous ammonia, $(Ag(NH_3)_2)^+$ is formed. A co-ordinate bond is formed from ammonia to silver ions, and the oxidation state of nitrogen remains -3. Ammonia molecules do not receive protons in this reaction, so ammonia does not act as a Brønsted-Lowry base, so only choices **1** and **2** are correct.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

This examination paper provided a difficult challenge to the candidates. There were some pleasing performances, but very few really good ones.

Twenty questions can be said to have been found to be easier. These were **Questions 3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**, **13**, **14**, **17**, **18**, **19**, **25**, **26**, **27**, **34**, **36**, **38** and **40**. Since **Questions 38** and **40** were both answered correctly by a significant number of candidates it is reasonable to suggest that most candidates found they had sufficient time to complete the paper properly.

Six questions can be said to have been found to be particularly difficult. These were **Questions 1**, **16**, **23**, **29**, **32** and **35**.

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

Question 1: The correct answer was **D**. The most commonly chosen incorrect answer was **C**. The key word in this question is **not**, which was in bold type. The use of bold type in a question is always significant. Choices **A**, **B**, and **C** will all increase the rate of the forward reaction used in the Haber process. Removing the ammonia as it is formed will result in a decrease in concentration of nitrogen and hydrogen, since it will stop the backward reaction, so this will **not** increase the rate of the forward reaction.

Question 16: The correct answer was **C**. The most commonly chosen incorrect answers were **B** and **D**. The relevant product of the first reaction (conc H_2SO_4 + KCl) is HCl. HCl will not react with KI(aq), so observation X is “colourless solution”. The second reaction was between KCl and $AgNO_3$ in the presence of ammonia solution. The expected product, $AgCl$, is soluble in ammonia solution, so observation Y is also “colourless solution”.

Question 23: The correct answer was **C**. The most commonly chosen incorrect answers were **A** and **B**. Candidates who answered **A** had possibly ignored the esters of methanoic acid. Candidates who answered **B** had possibly failed to appreciate that there are two esters of methanoic acid with the formula $C_4H_8O_2$, since C_3H_7 can be “straight chain”, or branched.

Question 29: **B**. The most commonly chosen incorrect answers were **A** and **D**. The key word in this question is **not**, which was in bold type. The reaction pathway has a “dip” in the middle, showing that the reaction has two steps and goes via an intermediate. Choices **A**, **C**, and **D** all do this, but choice **B** is a single step reaction that does not.

Question 32: The correct answer was **B**. The most commonly chosen incorrect answer was **D**. This suggests that most candidates appreciated that O and Cl^+ both have four p electrons, therefore providing one answer to the question. However, many candidates then failed to appreciate that F^+ with four p electrons has two unpaired p electrons, the same number as are present in Ga^-. Choices **1** and **2** are both correct.

Question 35: The correct answer was **A**. The most commonly chosen incorrect answer was **B**. This suggests that for most candidates their choice of answer rested on the truth or otherwise of choice **3**. If the operating pressure is increased for a process in which all reactants and products are gases then **both** the rate of the forward reaction and the rate of the backward reaction will increase, although by different amounts.

CHEMISTRY

Paper 9701/21
AS Structured Questions

Key Messages

There were many examples of candidates not reading questions carefully enough, and as a result, omitting state symbols in **Question 3(a)** or drawing the incorrect type of organic formula, such as structural instead of displayed in **Question 5(c)(i)**.

Some chemical equations offered, such as in **Questions 1(c)(ii)** and **3(a)**, contained mistakes in a formula or were unbalanced, suggesting that candidates had not checked their answers thoroughly.

In general, the structural formulae were quite well drawn but candidates should be encouraged to draw their structural formulae in a clear and unambiguous way. Information about the different types of formulae used in organic chemistry is given in ***Section 10.1*** of the syllabus.

One recurring error in candidates' formulae is the representation of the –OH group when it is the left-hand end of a molecule. For example, the structural formula of ethan-1.2-diol should be shown as $HOCH_2CH_2OH$ rather than $OHCH_2CH_2OH$. Displayed formulae showing the link OH–C are not accepted.

The setting out of answers to calculations continues to show that many candidates use a very illogical approach in which they do not state clearly what they are calculating. For example, in **Question 5(b)(ii)** sequences of numbers similar to the following were given.

$$\frac{0.600}{2}$$

$$\text{moles} = \frac{\text{mass}}{M_r} \qquad\qquad 0.066 =$$

$$\text{moles} = \frac{0.600}{90} = 0.066 \qquad\qquad \text{hydrogen atom } 0.033$$

This answer does not produce the correct result and the method used is full of contradictions. Such answers usually result in candidates making mistakes and it is very difficult for Examiners to give them much, if any, credit.

General comments

This paper tested the candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was similar to last year, with an encouraging performance in the calculation questions. Most candidates showed some positive achievement.

Questions 1 and **4** involved much factual recall and showed which candidates had concentrated on this aspect of their revision. Full credit was common for good candidates in **Question 2**, which involved mainly calculations. The calculation in **Question 3(b)(i)** was also well done and sound answers were given in **3(c)**. **Question 5** involved some organic problem solving where the better candidates provided good answers.

Comments on specific questions

Question 1

It is important in the study of AS Level Chemistry that candidates are able to describe and explain the important reactions of the elements of the third period of the Periodic Table. In this question there were some good answers to each part. However, many candidates' answers were marred by the lack of a clear description when it was required.

(a) Most candidates could recall this chemistry correctly; the most common error was describing SiO_2 as amphoteric.

(b) Some candidates gave symbols here instead of names as required in the question.

(c) (i) Most candidates were able to give at least two correct observations. Some, however, described things that were not relevant to the actual experiment such as 'the solution will turn litmus blue'.

(ii) In this part, the equation was often not balanced, or contained sodium oxide, Na_2O, as a product.

(d) (i) Many answers to this part were too vague, not specifying a chemical reaction. Examples included 'car engines' or 'factory emissions'.

(ii) This was generally well answered.

(iii) This too was well answered.

(e) 'Reducing agent' or 'anti-oxidant' were well known reasons for the use of SO_2 as a food preservative, while 'acidic' was a common incorrect answer.

(f) (i) There were many good diagrams of the arrangement of electrons in the OCS molecule. A common error was to have the O and / or S atoms surrounded by ten electrons.

(ii) A correct 'dot-and-cross' diagram was usually followed by the correct bond angle of 180°.

Question 2

The ability to work through a sequence of calculations, such as those in this question, is important in both the theory and the practical parts of AS Level Chemistry.

There were many correct answers to this question with candidates demonstrating good mathematical skills in working through the problem. Those candidates who were unable to obtain a correct value for the percentage purity of the ammonium sulfate fertiliser usually used a very unstructured and illogical approach to the calculation.

(a) The majority of candidates gave the correct products, Na_2SO_4 and H_2O. Those who offered $NaSO_4$ or H_2 could not balance the equation.

(b) Those candidates who made an error at an early stage of the calculation but then used their (wrong) answers correctly were given credit.

(i) The equation was well known by the majority of candidates.

(ii) This was generally correctly answered.

(iii) This too was well answered.

(iv) This was less well done with some candidates clearly not understanding the concept of back titration.

(v) Many candidates answered this correctly. Those who used their (wrong) answer to part **(iv)** correctly were given credit.

(vi) This was quite well done although some candidates were unable to calculate the M_r of $(NH_4)_2SO_4$ correctly. Those who used their (wrong) answer to part **(v)** correctly were given credit.

(vii) There were many candidates who used their answers to preceding parts correctly here.

Question 3

Questions that relate to chemical thermodynamics need to be answered carefully and accurately; Answers must not be ambiguous. While there were many good responses to this question, there were also many candidates who lost credit through a lack of care with equations, definitions or calculations.

(a) Many equations were incorrect because they were unbalanced, lacked or had incorrect state symbols.

Definitions of enthalpy change of formation were often insufficiently rigorous and sometimes vague. It was expected that the definition would begin with a phrase such as “the enthalpy change of formation is the enthalpy change when...”. Statements which began “it is when 1 mol of...” were not accepted.

Definitions that referred to ‘...the energy required to...’ were not accepted because enthalpy change of formation can be endothermic or exothermic.

(b) (i) Many candidates obtained the correct answer. The main errors seen were having the cycle the wrong way round and getting $+49\,kJ\,mol^{-1}$, or using bond energies from the *Data Booklet*.

Candidates were asked to include a sign in their answer; a significant number did not do this and were penalised.

(ii) Candidates usually realised that CO_2 was being used up in the reaction so, as it is a greenhouse gas, global warming would be reduced by the formation of methanol.

(c) Many candidates showed a good understanding of Le Chatelier’s principle in their answers. Only the very best candidates appreciated that with a catalyst the yield does not change because the forward and backward reactions are speeded up by the same amount.

Some answers talked about the rate of reaction for which no credit was awarded.

Question 4

Knowledge of the organic chemistry in the AS Level syllabus was generally more secure than in recent years. Many candidates must be congratulated on learning the necessary material very well. However, the presentation of structural, displayed and skeletal formulae still causes problems to many candidates. Information about these different types of formulae is given in ***Section 10.1*** of the syllabus.

(a) (i) This equation was generally well known.

(ii) Most candidates correctly identified the type of reaction. ‘Condensation’ was not accepted as a correct description.

(iii) Many candidates did not give the name of the reagent as required by the question. Those who gave ‘sulfuric acid’ as their reagent had to specify ‘concentrated’ in order to gain credit.

(b) This part was less well answered. Many candidates thought aqueous hydrogen bromide was brown, while others gave an organic product containing two bromine atoms rather than CH_3CH_2Br. The colour change was better known for the reaction with acidified potassium manganate(VII) as was the product $HOCH_2CH_2OH$.

(c) (i) Many candidates gave the correct molecular formula, C_6H_{10}. The most common incorrect answer was C_6H_{12}.

(ii) Those candidates who had answered part **(c)(i)** correctly usually gave a correct answer to this part.

(iii) This part was generally correctly answered.

(iv) There were fewer correct answers to this part. Those candidates who correctly drew displayed or skeletal formulae were given credit for their answers.

Some candidates gave cyclic structures or compounds which contained an aldehyde group. Such answers received no credit.

Question 5

This question involved application of knowledge of the reactions of functional groups to deduce the identities of some organic compounds. The better candidates solved the problems posed and scored full credit.

(a) This was generally correctly identified, the functional group being carboxylic acid. Examiners did not accept the answer 'acid' which was too vague.

(b) (i) Many candidates correctly stated that compound **X** must be an alcohol. Examiners did not accept 'hydroxyl' or '–OH' because these terms could include phenols which do not behave as described in the question.

(ii) Although the question asked candidates to calculate the amount, in moles, of hydrogen atoms, some candidates used the information given about compound **X** instead.

(iii) To answer this part satisfactorily, a clear link between the amount, in moles, of **X** and the amount, in moles, of hydrogen atoms produced must be established. Since each –OH group produces one H atom when reacted with Na, **X** must contain two –OH groups.

A small number of candidates unnecessarily used the Avogadro number in calculating the number of H atoms.

(c) (i) The aldehyde group needed to be displayed as requested and not shown as –CHO.

(ii) Many candidates correctly deduced that **X** was $HOCH_2CH(OH)CHO$. Incorrect answers after this stage were given credit in subsequent parts of the question if correct products were given to the reactions mentioned.

(iii) The answer that **X** was oxidised to $HOCH_2CH(OH)CO_2H$ was given by many candidates.

(d) (i) Knowledge of this reaction was less secure. **X** would be reduced to $HOCH_2CH(OH)CH_2OH$.

(ii) Oxidation products were slightly better known although some candidates failed to realise that aldehydes would not be formed when **X** was heated under reflux with acidified $K_2Cr_2O_7$. Compound **X** would be oxidised to HO_2CCOCO_2H.

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key Messages

There were many examples of candidates not reading questions carefully enough, and as a result, omitting state symbols in **Question 2(a)** or drawing the incorrect type of organic formula, such as structural instead of displayed in **Question 3(d)(i)**.

Some chemical equations offered, such as in **Questions 1(a)(iv)** and **2(a)**, contained mistakes in a formula or were unbalanced, suggesting candidates had not checked their answers thoroughly.

In general, the structural formulae were quite well drawn but candidates should be encouraged to draw their structural formulae in a clear and unambiguous way. Information about the different types of formulae used in organic chemistry is given in ***Section 10.1*** of the syllabus.

One recurring error in candidates' formulae is the representation of the –OH group when it is the left hand end of a molecule. For example, the structural formula of ethan-1.2-diol should be shown as $HOCH_2CH_2OH$ rather than $OHCH_2CH_2OH$. Displayed formulae showing the link OH–C are not accepted.

The setting out of answers to calculations continues to show that many candidates use a very illogical approach in which they do not state clearly what they are calculating. For example, in **Question 2(b)** sequences of numbers similar to the following were given.

$\Delta H^{\ominus}_{\text{reaction}}$

$\Rightarrow -283 + 2(-286) \rightarrow -726$

$\Rightarrow -855 = -726$

$\Rightarrow -855 + 726 = 0$

therefore $\Delta H^{\ominus}_{\text{reaction}} = -129\,\text{kJ mol}^{-1}$

This answer produces the correct result but the method used is full of contradictions. Such answers usually result in candidates making mistakes and it is very difficult for Examiners to give them much, if any, credit.

General comments

This paper tested the candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was similar to last year, with an encouraging performance in the calculation questions. Most candidates showed some positive achievement.

Questions 1 and **3** involved much factual recall and showed which candidates had concentrated on this aspect of their revision. The calculation in **Question 2** was well done by many candidates. However, the calculations in **Questions 3(e)** and **4(b)** saw fewer fully correct answers. **Question 4** involved some organic problem solving where the better candidates provided good answers.

Comments on specific questions

Question 1

It is important in the study of AS Level Chemistry that candidates are able to describe and explain the important reactions of the elements of the third period of the Periodic Table. In this question there were some good answers to each part. However, many candidates' answers were marred by the lack of a clear description when it was required.

(a) (i) This was correctly answered by many candidates.

(ii) Fewer candidates gave a correct response to this part with 'magnesium' being a common incorrect answer. Some candidates gave a symbol rather than the required name and received no credit.

(iii) While many candidates were able to give one correct observation, few gave two that were accepted. Some answers, such as 'see dimeric Al_2Cl_6 being formed' were clearly taken from theory and not practical observation.

(iv) A correct equation for the formation of either $AlCl_3$ or Al_2Cl_6 was given by the majority of candidates. However, a significant number failed to balance their equations, gave no state symbols, or gave ones which were incorrect. One common error of a different kind was to represent the formula of aluminium chloride as Al_2Cl_3.

(v) There were many sensible answers to this part, either in terms of a very high activation energy, or because the outermost (valency) shell of electrons is completely full. Candidates who simply said 'argon is inert' or 'argon is a noble gas' received no credit.

A significant number of candidates stated that argon contained a 'full octet' or 'complete shell' of electrons, without fully appreciating that it has more than one full shell or complete octet.

(b) (i) There were relatively few completely correct answers to this part. Some candidates did not know which chlorides reacted with water and even more could not give a correct pH value for each solution formed.

(ii) This was poorly answered with relatively few candidates stating that the reaction is an example of hydrolysis.

(c) (i) The majority of candidates deduced that the nitrogen atom would have one lone pair of electrons while the sulfur atom would have two lone pairs.

(ii) There were some very good answers to this part with many candidates identifying the bond angle at the sulfur atom as the smaller of the two. They then explained this by stating clearly the repulsive effects of the two lone pairs around the sulfur atom on the two bond pairs that are also there. However, an appreciable number of candidates did not link the number of lone pairs on an atom with the associated increased repulsion.

Question 2

Questions that relate to chemical thermodynamics need to be answered carefully and accurately. Answers must not be ambiguous. While there were many good responses to this question, there were also many candidates who lost credit through a lack of care with definitions or calculations.

(a) Many equations were incorrect because they were unbalanced, lacked or had incorrect state symbols.

With regard to state symbols, many candidates incorrectly gave $H_2O(g)$ instead of $H_2O(l)$ for water at 298 K. A small number thought that CH_3OH is a gas at room temperature.

A small number of candidates wrote an equation in terms of $2CH_3OH$ which cannot be used for the enthalpy change of combustion of one mole of CH_3OH.

Definitions of $\Delta H^{\ominus}_{c}$ were often insufficiently rigorous and sometimes extremely vague. It was expected that the definition would begin with a phrase such as 'the enthalpy change of combustion is the enthalpy change when...'. Statements which began 'it is when 1 mol of...' were not accepted.

Definitions that referred to '...the energy required to...' were not accepted because combustion is always exothermic.

(b) While many candidates obtained the correct answer, there were still many who did not. The most common error was to overlook the two moles of H_2 in the equation; some candidates calculated the value of $\Delta H^{\ominus}_{reaction}$ for the reverse reaction.

Candidates were asked to include a sign in their answer; a significant number did not do this and were penalised.

A small number of candidates used bond energy data from the *Data Booklet* and received no credit for their answers.

(c) There were some very good clear answers to this question; there were also many answers which showed that candidates did not fully understand the effect of each of the conditions quoted on the rate of formation of methanol.

Many candidates referred to the effects of pressure, temperature and the presence of a catalyst on the position of equilibrium despite the fact that no equilibrium was shown in the equation and the question referred very clearly to the effects of the conditions used on the **rate of formation** of methanol.

Those candidates who did discuss the effects of the conditions on the rate of formation of methanol often failed to make it clear to Examiners that a higher temperature results in more molecules having energy greater than the activation energy so that more successful collisions between molecules take place. Answers which simply referred to an increase in the kinetic energy of molecules were not accepted.

Question 3

Knowledge of the organic chemistry in the AS Level syllabus was generally more secure than in recent years. Many candidates must be congratulated on learning the necessary material very well. However, the presentation of structural, displayed and skeletal formulae still causes problems to many candidates.

(a) There were many fully correct answers to this part with candidates demonstrating good knowledge of the reactions involved. There were, however, some candidates who were penalised because some of their structures were not unambiguous.

For example, the correct structural formula of the di-ester that is compound **A** is:

$$CH_3O_2CCH_2CH(OH)CO_2CH_3$$

However, a significant number of candidates represented this compound as:

$$CH_3CO_2CH_2CH(OH)CO_2CH_3$$

This structure actually represents an ester of ethanoic acid rather than the required product.

Many candidates answered this part by drawing displayed rather than structural formulae, which were accepted.

(b) This was well answered by many candidates.

(c) The majority of candidates suggested an appropriate commercial use of the esters concerned.

(d) (i) There were many good diagrams of the two enantiomers of malic acid with most candidates correctly identifying the chiral carbon atom. Fewer candidates gave a clear 3-dimensional representation, while many failed to give a fully displayed formula of the molecule of malic acid in which all bonds were clearly shown. One very common error was the representation of the hydroxyl group as –OH instead of –O–H.

(ii) This was less well answered although many candidates correctly identified, in part **(a)**, compound **C** as butenedioic acid. Many of these answers correctly showed the *cis* and *trans* forms of this acid as displayed structures, but there were relatively few correct skeletal formulae.

(e) There were few fully correct answers to this part. The majority of answers correctly used relevant A_r values to obtain the first set of ratios. However, at this stage many candidates, rather than dividing each value by the smallest, carried out an approximation which usually led to the ratio 1 : 1 : 1.

Only a relatively small number of candidates persisted with the calculation as shown above and obtained the second set of ratios.

At this stage too there were, once again, some examples of unsound approximation so that correct final answers were relatively uncommon.

Question 4

This question required candidates to apply their knowledge of organic reactions in an unfamiliar context. There were some good answers although a significant number of candidates struggled with the calculation in part **(b)**.

(a) This was generally well answered with many candidates correctly identifying five reactions. Those candidates who ignored the instruction to '...place **no more** than five ticks in the table...' were penalised.

(b) (i) Many candidates correctly stated that compound **G** must be an alcohol. Examiners did not accept 'hydroxyl' or '–OH' because these terms could include phenols which do not behave as described in the question.

(ii) While there were some very good answers to this part, many candidates struggled, and a significant number failed to use all of the data in the question. In particular the reference to '80 cm^3 of H_2, measured at room temperature and pressure' was often overlooked.

A small number of candidates unnecessarily used the Avogadro number in calculating the number of H atoms.

(iii) To answer this part satisfactorily, a clear link between the amount, in moles, of **G** and the amount, in moles, of hydrogen atoms produced must be established. Since each –OH group produces one H atom, **G** must contain two –OH groups. Many candidates used some or all of the data in the question, but failed to establish a clear link, and received no credit for this part.

(c) (i) This part was well answered with most candidates drawing an acceptable displayed formula of the ketone group.

(ii) Many candidates correctly deduced that **G** had the molecular formula $C_3H_6O_3$. Using their earlier answers they were then able to give the structural formula for **G**.

(d) (i) There were fewer correct answers to this part with some candidates failing to oxidise the alcohol groups fully to carboxylic acid.

(ii) The reduction of **G** was generally correctly done to give **J**.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key messages

There were many examples of candidates not reading questions carefully enough, and as a result, omitting state symbols in **Question 3(a)** or drawing the incorrect type of organic formula, such as displayed instead of skeletal in **Question 4(d)(i)**.

Some chemical equations offered, such as in **Questions 1(c)(iii)** and **3(a)**, contained mistakes in a formula or were unbalanced, suggesting candidates had not checked their answers thoroughly.

In general, the structural formulae were quite well drawn but candidates should be encouraged to draw their structural formulae in a clear and unambiguous way. Information about the different types of formulae used in organic chemistry is given in ***Section 10.1*** of the syllabus.

One recurring error in candidates' formulae is the representation of the –OH group when it is the left-hand end of a molecule. For example, the structural formula of ethan-1.2-diol should be shown as $HOCH_2CH_2OH$ rather than $OHCH_2CH_2OH$. Displayed formulae showing the link OH–C are not accepted.

The setting out of answers to calculations continues to show that many candidates use a very illogical approach in which they do not state clearly what they are calculating. For example, in **Question 5(c)** sequences of numbers similar to the following were given.

$$\text{mol} = \frac{0.600}{90} = \frac{2}{300} \Rightarrow \frac{2 \times 24}{300} = 160$$

Numerically, the answer 160 is correct but the candidate has not made clear whether this is the number of moles or a volume - which has no units. Such answers usually result in candidates making mistakes and it is very difficult for Examiners to give them much, if any, credit.

General comments

This paper tested the candidates' knowledge and understanding of important aspects of AS Level Chemistry. The overall standard achieved by candidates was somewhat improved compared to last year, with an encouraging performance in the calculation questions. Most candidates showed some positive achievement.

Questions 1 and **4** involved much factual recall and showed which candidates had concentrated on this aspect of their revision. Full credit was common for good candidates in **Question 2** which mainly involved calculations. The calculation in **Question 3(b)** was also well done and there were some sound answers to part **3(c)**. **Question 5** involved some organic problem solving where the better candidates provided good answers.

Comments on specific questions

Question 1

It is important in the study of AS Level Chemistry that candidates are able to describe and explain the major trends in the chemistry of the elements of the third period of the Periodic Table. In this question there were many good answers to all parts of the question. However, some candidates' answers were marred by the lack of a clear explanation when it was required.

(a) (i) The majority of candidates correctly stated that from Na to C*l* there are more protons in the nucleus. Fewer stated clearly that this gives an increased nuclear attraction for electrons. Fewer still explained that from Na to C*l* the electrons are in the same shell and experience the same shielding.

(ii) This was very well answered by many candidates who explained that argon exists as a monatomic gas which does not form any compounds. The statements 'argon is a noble gas' or 'argon is inert' were not accepted as explanations.

(b) (i) Almost all candidates retrieved the correct data from the *Data Booklet*.

(ii) This part was less well answered. It was expected that candidates would compare the numbers of electrons in the cation with those in the parent atom and explain that the greater number of protons would pull the remaining electrons closer to the nucleus. Some candidates did this in terms of all of the electrons in the outer shell of an atom being removed to form the corresponding cation.

(iii) For anions the reverse argument was expected but explanations were generally not as clearly made.

(c) (i) There were many correct equations for both oxides but a significant number of candidates gave unbalanced equations or gave an incorrect product. The most common of these was the production of H_2SO_4 in the reaction of SO_2 with H_2O.

(ii) Correct values of pH were given by most candidates.

(iii) This part was less well done with many equations containing simple errors. Typical examples of incorrect answers were the following equations which appeared quite often.

$$NaOH + H_2SO_3 \rightarrow Na_2SO_3 + H_2O$$

$$2NaOH + H_2SO_3 \rightarrow Na_2SO_4 + H_2O$$

Question 2

The ability to work through a sequence of calculations, such as those in this question, is important in both the theory and the practical parts of AS Level Chemistry.

There were many correct answers to this question with candidates demonstrating good mathematical skills in working through the problem. Those candidates who were unable to obtain the correct value of x in $Na_2CO_3.xH_2O$ usually had a very unstructured and illogical approach to the calculation.

(a) (i) This was generally correctly answered although a small number of candidates gave unbalanced equations.

(ii) The majority of candidates gave a correct answer to this part.

(iii) This too was well answered by most candidates.

(iv) Again, a large number of candidates answered this correctly.

(v) There were fewer correct answers to this part, with a number of candidates giving a wrong value for M_r of Na_2CO_3, either by using proton numbers rather than values of A_r or by arithmetical error.

(b) A significant number of candidates struggled with this part. Some did not know how to use the answers they had calculated in part **(a)**, while others used wrong data or made arithmetical errors.

Question 3

Questions that relate to chemical thermodynamics need to be answered carefully and accurately. Answers must not be ambiguous. While there were many good responses to this question, there were also many candidates who lost credit through a lack of care with definitions or calculations.

(a) Many equations were incorrect because they were unbalanced, because they lacked state symbols, or because the latter were wrong.

With regard to state symbols, many candidates incorrectly gave $H_2O(g)$ instead of $H_2O(l)$ for water at 298 K. A small number gave $CH_3OCH_3(l)$ despite information in the question that DME is a gas.

A small number of candidates wrote an equation in terms of $2CH_3OCH_3$ which cannot be used for the enthalpy change of combustion of one mole of CH_3OCH_3.

Definitions of $\Delta H^{\ominus}_c$ were often insufficiently rigorous and sometimes extremely vague. It was expected that the definition would begin with a phrase such as 'the enthalpy change of combustion is the enthalpy change when...'. Statements which began 'it is when 1 mol of...' were not accepted.

Definitions that referred to '...the energy required to...' were not accepted because combustion is always exothermic.

(b) While many candidates obtained the correct answer, there were still many who did not. The most common error was to overlook the two moles of CH_3OH in the equation; Some candidates calculated the value of $\Delta H^{\ominus}_{reaction}$ for the reverse reaction.

Candidates were asked to include a sign in their answer; a significant number did not do this and were penalised.

A small number of candidates used bond energy data from the *Data Booklet* and received no credit for their answers.

(c) (i) Most candidates drew two correct displayed formulae. One common error was to show the hydroxyl group in ethanol as O–H–C rather than H–O–C. A small number of candidates drew two structures for ethanol that, at first sight, appeared to be different.

(ii) This was correctly answered by many candidates.

(d) (i) There were fewer correct answers to this part with 'van der Waals' forces' a common wrong response.

(ii) Many candidates drew very good clear diagrams which showed, as the question required, the relevant dipoles and lone pairs. Some candidates failed to show the dipole on <u>one</u> –O–H bond, putting the $\delta+$ and $\delta-$ charges on atoms in two separate molecules instead. A number of candidates also lost credit for failing to show clearly that the hydrogen bond exists between the lone pair of an oxygen atom in one ethanol molecule and the hydrogen atom of the –OH group in another ethanol molecule.

Question 4

Knowledge of the organic chemistry that is examined at AS Level is only gained by learning the relevant material. Candidates' performance in this question suggests that many candidates have worked hard to learn the chemistry because answers were, in general, better than those seen in last year's examination. However, there were still candidates who clearly had not done the necessary learning.

(a) The majority of answers to this part were correct.

(b) Many correct equations were given in answer to this part. A small number of candidates received no credit because their equations contained hydrogen or were unbalanced.

(c) Many candidates scored well in this part with the structural formulae of correct compounds clearly shown. This was particularly true for compounds **B** and **C**. There were fewer correct answers for compound **A** which was frequently shown as ethanal rather than ethanoic acid. Answers for compound **D** were the least well done with candidates giving some very strange looking oxidation products such as $CH_3CH_2CH_2CH_3$ and $CH_3CHOCHOCH_3$.

(d) (i) This was well answered by many candidates.

(ii) Fewer candidates were able to deduce the identities of the two compounds, **B** and **C**, that were chiral.

(e) This was quite well answered but some candidates gave structures which contained 5-valent carbon atoms.

(f) (i) This part tested candidates' ability to apply familiar reactions to compounds they probably had not encountered before. There were some very good answers.

(ii) Most of the candidates who had stated that buta-1,3-diene was produced in part **(i)** gave the correct tetrabromo- derivative in this part.

(iii) This was generally well answered although some candidates confused electrophilic and nucleophilic addition.

Question 5

Although this question included a somewhat unusual calculation, there were many good answers. As with earlier questions, the structural formulae produced by some candidates were not always clearly drawn.

(a) (i) The majority of candidates correctly identified the gas **G** as CO_2.

(ii) This too was generally well answered with candidates identifying the functional group present in **F** as a carboxylic acid group. The answer 'acid' was not accepted because this could refer to any acid such as hydrochloric.

(b) (i) Although 'oxidation' was the most common wrong answer, most candidates gave a correct response to this part.

(ii) From the information given in the question, many candidates realised that compound **H** was a carboxylic acid which also contained a >C=C< bond. However there were many wrong answers most of which showed that candidates did not know the use of cold dilute acidified $KMnO_4$ as a test for an alkene. A small number thought that a cyclic ester would be formed.

(c) Many candidates struggled with this part, often because they did not adopt a logical approach to the problem.

From the information given in the question it can be shown that compound **F** contains one –OH group and one $–CO_2H$ group. Thus one mole of **F** produces one mole of H_2 when reacted with an excess of Na. Some candidates explained this by means of a chemical equation.

(d) (i) Many candidates were able to draw at least one structural formula of the isomers of compound **F**.

(ii) This part was quite well answered. The most common incorrect answer was to give an aldehyde for the oxidation product of **F**, despite the compound being heated under reflux with acidified $K_2Cr_2O_7$.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key Messages

- Candidates should be encouraged to read each question carefully before starting to answer.
- When drawing a line of best fit, candidates should be encouraged to circle any anomalous points which are not to be considered.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- It is important that candidates have carried out a wide range of practical exercises during their AS Chemistry course.

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, their experimental data for **Question 1** 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. This is important in reactions involving rates as the ambient temperature may differ in different laboratories or at different times of day. Also, all Centres running more than one session, and/or using more than one laboratory, should 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 Cambridge International Examinations but this is often unobtainable and candidates may be disadvantaged as a consequence.

Almost all the candidates divided their time successfully and so completed the paper, although a few, weaker candidates appeared to have rushed or omitted some of the parts of **Question 1** or **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work successfully in this question, and most were able to gain at least partial credit in both the calculation and the graph sections. It was disturbing to note that, in some cases, Supervisor values for the times of the reaction were so long or so short that the award of credit for accuracy based on comparison of these with candidate values was not really valid. There were a few Centres where the Supervisor reported that the reaction mixture did not go blue/black. This suggests that they were possibly using incorrect reagents or incorrect concentrations of the reagents.

(a) The majority of candidates drew sensible tables for their results but a significant number did not obey the instruction to record the time to the nearest second. The other instruction ignored by some was to use a minimum of 6 cm^3 of **FA 1**, and some chose additional volumes of **FA 1** that did not optimise the range of their results. However, it was pleasing to note that nearly all candidates realised that the total volume of the reaction mixture must stay the same. The award of credit for accuracy appeared to be consistent with the standard of the rest of the candidates' papers with the exceptions noted above.

(b) Most candidates calculated the correct numbers of moles in **(i)** and **(ii)**. Fewer calculated the concentration of iodine correctly in **(iii)** since they did not use the total volume of the reaction mixture.

(c) Rates were generally calculated correctly, although a few candidates did not record their answers to a minimum of two significant figures. Candidates should be reminded that the rounding of their answers must be numerically correct. Many candidates did not give a unit for rate; they should be encouraged to use any given formula to help work out a correct unit.

(d) Almost all candidates labelled axes suitably and chose linear scales. Candidates should be reminded that, although the scale chosen should mean that plotting of points should cover more than half the available paper in each direction, the choice of a 'difficult' scale to try to use all the page should be avoided. If, for example, a scale is chosen where a small square is 0.33 or 0.17, errors in plotting are much more likely than when a square is 0.5 or 1.0. Most candidates used a ruler to draw a straight line of best fit. It is important that the distances of points either side of the line are similar, hence the comment about anomalies in the Key Messages.

(e) Most candidates correctly stated that the rate increased when the concentration of **FA 1** increased. However, as the graph showed a straight line with a positive gradient, it was possible to describe the rate as being **directly proportional** to the concentration. This was particularly apparent for those who had correctly plotted (0,0), and these candidates tended to answer this part more fully.

(f) Many candidates answered **(i)** correctly but only the more able gave correct answers to **(ii)**. To achieve a minimum error the denominator has to be a maximum and **Experiment 1** (time – 0.5) instead of (time + 0.5) was seen from a substantial number of candidates. Candidates who gave an appropriate source of error were generally able to suggest a suitable modification in **(iii)**. Human reaction time is negligible compared with possible errors in judging the intensity of the blue-black colour or the effect of varying temperature during the run of experiments.

(g) To gain full credit it was necessary for candidates to note that the concentration of **FA 3** had been doubled and then link this with the increased time or decreased rate of reaction. A large number of candidates merely stated that this reaction was slower than that in **Experiment 2** without attempting to give a reason for the change.

Question 2

It was apparent that the response to this question was often Centre dependent; candidates from some provided very good answers to most parts. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. Candidates carrying out additional tests, contrary to instructions, may lose credit by providing inadmissible evidence for the presence of a correct ion.

(a) Many candidates recorded correct observations for more than one mixture. However, there are still some who do not use the precision of language required at this level: 'cloudy white solution' is not acceptable for 'white precipitate'.

(b) Most candidates who completed **(a)** successfully identified some, if not all, of the ions present.

(c) It was evident that candidates were aware of the tests required but many did not note the instruction that 'where reagents are selected for use in a test, the full name or correct formula of the reagents must be given': credit was not available for Ba^{2+} in **(i)** or a strong acid in **(ii)**. A few candidates chose to add dilute sulfuric acid to the precipitate formed between the barium ions and the anion in **FA 9** which meant that the credit for 'precipitate insoluble' was not available. However, if the sulfuric acid had been added to a separate sample of **FA 9**, and the test for SO_2(g) was negative, the credit for observation and conclusion could have been awarded. Some candidates did not recognise that they had only one compound on which to carry out their suggested tests: tables that included results for both possible ions (sulfite/sulfate) were not acceptable. In some cases, it appeared that candidates had copied the relevant sections from the Qualitative Analysis Notes rather than carrying out the tests themselves.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key Messages

- Candidates should be encouraged to read each question carefully before starting to answer.
- When drawing a line of best fit, candidates should be encouraged to circle any anomalous points which are not to be considered.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- It is important that candidates have carried out a wide range of practical exercises during their AS Chemistry course.

General comments

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Examiners take steps to obtain the missing data through Cambridge International Examinations but this is often unobtainable and candidates may be disadvantaged as a consequence.

Almost all the candidates divided their time successfully and so completed the paper, although a few, weaker candidates appeared to have rushed or omitted some of the parts of **Question 1** or **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

Comments on specific questions

Question 1

The majority of the candidates were able to complete the practical work in this question, and most were able to gain credit both in the calculation and the graph sections. It was disturbing to note that, in some cases, Supervisor values for the times of the reaction were so long or so short that the award of credit for accuracy based on comparison of these with candidate values was not really valid.

(a) The majority of candidates drew sensible tables for their results but a significant number did not obey the instruction to record the time to the nearest second. The other instruction ignored by some was to use a minimum of 6 cm^3 of **FB 1**, and some chose additional volumes of **FB 1** that did not optimise the range of their results. However, it was pleasing to note that nearly all candidates realised that the total volume of the reaction mixture must stay the same. The award of credit for accuracy appeared to be consistent with the standard of the rest of the candidates' papers with the exceptions noted above.

(b) Many candidates calculated the correct numbers of moles in **(i)**, **(ii)** and **(iii)**. Fewer used the value from **(iii)** to calculate the decrease in concentration of iron(III) ions in **(iv)**.

(c) Rates were generally calculated correctly, although a few candidates did not record their answers to a minimum of two significant figures. Candidates should be reminded that the rounding of their answers must be numerically correct. Many candidates did not give a unit for rate; they should be encouraged to use any given formula to help work out a correct unit.

(d) Almost all candidates labelled axes suitably and chose linear scales. Candidates should be informed that, although the scale chosen should mean that plotting of points should cover more than half the available paper in each direction, the choice of a 'difficult' scale to try to use all the page should be avoided. If, for example, a scale is chosen where a small square is 0.33 or 0.17 errors in plotting are much more likely than when a square is 0.5 or 1.0. Most candidates used a ruler to draw a straight line of best fit. It is important that the distances of points either side of the line are similar, hence the comment about anomalies in the Key Messages.

(e) Most candidates correctly stated that the rate increased when the concentration of **FB 1** increased. However, as the graph showed a straight line with a positive gradient, it was possible to describe the rate as being **directly proportional** to the concentration. This was particularly apparent for those who had correctly plotted (0,0), and these candidates tended to answer this part more fully.

(f) Where two readings are required from a measuring instrument to find a quantity used, it is necessary to double the error of a single reading when finding the percentage error. This was omitted by some candidates in **(i)**. Human reaction time is negligible compared with other possible errors such as judging the colour change or the effect of varying temperature during the run of experiments. Only the most able candidates suggested a possible reaction between Fe^{3+} and $S_2O_3^{2-}$ in **(iii)**. Most suggestions lacked precision, such as one of the reactants possibly being oxidised by air.

(g) To gain full credit it was necessary for candidates to note that the concentration of **FB 3** had been halved and then link this with the decreased time or increased rate of reaction. A large number of candidates merely stated that this reaction was faster than that in **Experiment 2**, without attempting to give a reason for the change.

Question 2

It was apparent that the response to this question was often Centre dependent; candidates from some provided very good answers to most parts. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. Candidates carrying out additional tests, contrary to instructions, may lose credit by providing inadmissible evidence for the presence of a correct ion.

(a) Many candidates recorded correct observations for more than one mixture. However, there are still some who do not use the precision of language required at this level: 'cloudy yellow solution' is not acceptable for 'yellow precipitate'.

(b) Most candidates who completed **(a)** successfully identified some, if not all, of the ions present.

(c) It was evident that candidates were aware of the tests required but many did not note the instruction that 'where reagents are selected for use in a test, the full name or correct formula of the reagents must be given': credit was not available for aluminium with OH^- in **(i)** or a strong acid in **(ii)**. Precision of language is important as candidates had to indicate that it was a gas that turned red litmus blue when carrying out the test suggested in **(i)**. Some candidates did not recognise that they had only one compound on which to carry out their tests: tables that included results for both possible ions (nitrite/nitrate) were not acceptable. In some cases, it appeared that candidates had copied the relevant sections from the Qualitative Analysis Notes rather than carrying out the tests themselves.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Candidates should be encouraged to read each question carefully before starting to answer.
- When drawing a line of best fit, candidates should be encouraged to circle any anomalous points which are not to be considered.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- It is important that candidates have carried out a wide range of practical exercises during their AS Chemistry course.

General comments

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Examiners take steps to obtain the missing data through Cambridge International Examinations but this is often unobtainable and candidates may be disadvantaged as a consequence.

Almost all the candidates divided their time successfully and so completed the paper, although a few, weaker candidates appeared to have rushed or omitted some of the parts of **Question 1** or **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

Comments on specific questions

Question 1

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

(a) The majority of candidates gave a value for the rough titres and burette readings for the accurate titres as instructed, and gave appropriate headings and units for the weighing and accurate titration tables. Others omitted the burette readings for their rough titre values. There are still Centres whose candidates do not give burette readings consistently to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to waste 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. The difficulty of using methyl orange indicator, and the problems likely to arise from titrating the diluted mixture from **Step 1**, were both taken into consideration when awarding credit for accuracy in **Step 3**. Generally, the awarding of credit for accuracy tended to be Centre dependent, although there were good results from some individual candidates where others from the Centre had performed poorly.

(b) The majority of candidates selected appropriate titres for the mean, and were able to provide suitable answers to **(ii)** and **(iii)**. Part **(iv)** caused more difficulty as many candidates assumed the concentration of the hydrochloric acid, **FA 2**, to be exactly 1 mol dm^{-3} instead of using their answers from **(iii)** to find the number of moles. Of those who correctly used **(iii)**, many did not incorporate the dilution factor.

(c) The majority of candidates selected appropriate titres for the mean in **(i)**. However, a number used the value for the rough titration or used titres which were outside the usual 0.20 cm^3 range. Many candidates scored full credit in this section, showing a good understanding of the use of mole ratios, and set the work out clearly and elegantly. Most candidates showed their working in all sections of **(b)** and **(c)**.

(d) Almost all candidates were able to balance the equation in **(i)**, although a surprising number gave H_2CO_3 as a product of the reaction. This was credited even though it would have been unusual for a candidate not to observe copious bubbling in **(a) Step 1**. Better candidates used the mole ratio from the balanced equation so calculated a mass of $CaCO_3$ which was less than the mass of **FA 4** used. A number of candidates used the default value for the number of moles of hydrochloric acid in **(iii)** even when **(ii)** had been correctly calculated. Candidates who did not use the mole ratio in **(iii)** tended to invert the ratio of masses in **(iv)** rather than calculate a percentage purity which would be over 100%. Many recorded their final answers to three or four significant figures in parts **(b)**, **(c)** and **(d)**, though this tended to be Centre dependent, with a few rounding their answers to one significant figure.

(e) Only a minority of candidates gained the credit here. Many did not note that the error in a **single** burette reading was needed in **(i)**, and then did not double the answer to **(i)**, or used the volume of **FA 1** from **(c)(i)**, when calculating the maximum percentage error in **(ii)**.

(f) Few candidates appeared to understand the question or answer it successfully. Some of the suggested improvements and explanations were contradictory. Many did not provide an explanation for their suggestions, and some confused ‘percentage error’ and ‘percentage mass error’.

Question 2

It was apparent that the response to this question was often Centre dependent; candidates from some provided very good answers to most parts. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is important that candidates note the states of products as well as changes in colour, and test gases when effervescence is observed.

(a) Candidates should be encouraged to indicate changes in appearance which incorporate both colour and state. There was an apparent misunderstanding of ‘precipitate’ as some used the word when adding a solid to a solution as in **(vii)**. The fine distinction between the solution colour and the gradual formation of the darker precipitate in **(vi)** was rarely made, although many were able to gain credit for describing a brown solution or brown precipitate. It would appear that some candidates did not warm the tube in **(viii)** for long enough, or removed the litmus paper as soon as it turned red, so did not observe the bleaching effect of the chlorine. However, those who tested the gas evolved in **(i)** or in **(vii)** with a glowing splint successfully identified oxygen as the gas evolved.

(b) Many candidates successfully identified manganese in **(i)** as the transition metal present in the three compounds tested in **(a)**. Candidates should ensure that sufficient evidence is quoted and that it comes from their observations. The descriptions given in the Qualitative Analysis Notes should be used. Although ‘redox’ was the expected response in **(ii)**, a similar number of candidates gave ‘oxidation’ as their answer without specifying which ion had been oxidised. The majority of candidates answered the first part of **(iii)** correctly although slightly fewer gave an oxidation number between +2 and +7 for the second part, and even negative oxidation states were seen.

(c) Most candidates gave the names or correct formulae of suitable reagents in **(i)**, and a large majority gained further credit for the unambiguous layout of the tests and observations. A surprising number reported a cream precipitate with $AgNO_3$ and **FA 8** in **(ii)**, or gave cream/yellow as the response. Some candidates gave the correct identities in **(iii)** from incorrect or no reported observations so credit could not be awarded. The better candidates were able to provide the expected observation for **FA 8** in **(iv)**, though some merely stated that iodine would be formed, so no credit could be awarded. Fewer realised that the chloride ion would be a weaker reducing agent than the iodide ion so credit was infrequently awarded. There were many correct responses to **(v)**.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key Messages

- Candidates should be encouraged to read each question carefully before starting to answer.
- When drawing a line of best fit, candidates should be encouraged to circle any anomalous points which are not to be considered.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- It is important that candidates have carried out a wide range of practical exercises during their AS Chemistry course.
- Where two readings are required from a measuring instrument to find a quantity used, it is necessary to double the error of a single reading to find percentage error.
- Observations should be recorded in detail for each part of the instruction.

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, their experimental data for the three steps of **Question 1** 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. Those Supervisors who do not repeat titrations to ensure they are accurate may disadvantage some of their better candidates whose results may not secure the highest credit for accuracy while still being within the tolerances for that Centre. In addition, 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 Cambridge International Examinations but this is often unobtainable and candidates may be disadvantaged as a consequence.

Almost all the candidates divided their time successfully and so completed the paper, although a few, weaker candidates appeared to have rushed or omitted some of the parts of **Question 1** or **Question 2**.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

Comments on specific questions

Question 1

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

(a) The majority of candidates gave a value for the rough titres and burette readings for the accurate titres as instructed, and gave appropriate headings and units for the weighing and accurate titration tables. Others needed to include the burette readings for their rough titre values. There are still Centres whose candidates do not give burette readings consistently to 0.05 cm^3, and there were even a few candidates who recorded the burette readings as an integer. Some candidates appeared to waste 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. The difficulty of titrating a hot solution was taken into consideration when awarding credit for accuracy in **Step 2**. Generally the credit awarded for accuracy tended to be Centre dependent although some individual candidates scored good results where others from the Centre had performed poorly.

(b) The majority of candidates selected appropriate titres for the mean, and provided a correct, balanced equation in **(ii)**. Parts **(iii)** and **(iv)** caused little difficulty, with many candidates correctly using the mole ratio from **(ii)**.

(c) The majority of candidates selected appropriate titres for the mean in **(i)**. However, a number of candidates used the value for the rough titration, used titres which were outside the usual 0.20 cm^3 range, or did not indicate which titres they were using in the calculation. Almost all candidates scored credit for the parts involving mole ratios. Some had difficulty with the calculation in **(iv)** and would have benefited from referring back to the introduction in part **(a)**. Many candidates showed working in the right direction in all the calculation sections of **(b)** and **(c)**.

(d) Most candidates calculated the correct formula masses in **(i)** and **(ii)**. Many followed the instructions successfully and calculated the masses of the two chemicals correctly. A number used the default value for the number of moles of ethanedioic acid in **(i)** and sodium ethanedioate in **(ii)** even when the values in **(b)(iv)** and **(c)(iv)** had been correctly calculated. Some candidates did not use the total mass of the compounds when calculating the percentage by mass of sodium ethanedioate in **(iv)**. Many recorded their final answers to three or four significant figures in parts **(b)**, **(c)** and **(d)**, though this tended to be Centre dependent, with a few rounding their answers to one significant figure, and some being inconsistent or numerically incorrect in the rounding.

(e) Only a minority of candidates gained the credit here. Many did not note that the error in a **single** burette reading was needed in **(i)**, and then did not double the answer to **(i)** for use in **(ii)**. Only a few did not compare the percentage error of the two pieces of equipment.

(f) Few candidates appeared to understand the question. Again, reference to part **(a)** would have been of benefit as the concentration of **FB 4** was given as ‘approximate’ and the volume to be used was given as ‘about’. Only those who had experienced redox titrations using potassium manganate(VII), or those who looked carefully at the relevant equation and given concentrations, would have appreciated that the acid was present in large excess.

Question 2

It was apparent that the response to this question was often Centre dependent; candidates from some provided good answers to many parts. Careful adherence to the instructions was required as well as an appreciation of what constituted an observation. It is important that candidates note the states of products as well as changes in colour for each stage of a test, and carry out suitable tests for gases when effervescence is observed.

(a) When gases are evolved, as in **(i)**, there should be mention of effervescence, bubbling or fizzing. Many candidates omitted this observation, and so lost credit even though they correctly reported that the gas was brown and the solution turned blue. Some did not distinguish the difference in colour of the solution and the precipitate in **(ii)**. There was an apparent misunderstanding of ‘precipitate’, as some used the word when adding a solid to a solution as in **(iii)**, although many candidates gained credit here. Although ‘sublimation’ does not appear in the syllabus, tests are frequently set where careful observations but no inferences are required, and **(iv)** came in this category. The fine distinction between the solid in the bottom of the tube 'disappearing' and reforming further up the tube would have been observed provided only gentle heating was carried out. The majority of candidates were able to distinguish ammonia in **(v)** but subsequently forfeited credit by stating that ammonia was also given off in **(vii)**. Candidates should be given practice in tests involving negative results, and should be encouraged to think about the conclusions that can be drawn from them. Many of those finding ammonia in **(vii)** did so as they incorrectly added aluminium to the reaction mixture. Candidates should be reminded that 'no additional tests for ions present should be attempted'. Few candidates reported the colour of the solid formed when **FB 7** was allowed to cool after strong heating.

(b) A good number of candidates successfully identified nitrogen in **(i)** as the non-metal present in the three compounds tested in **(a)**, although some lost credit for writing the formulae of the ions. Many candidates answered the first part of **(ii)** correctly, though far fewer gave the expected oxidation number in **FB 6**. While 'redox' was the expected response in **(iii)**, a greater number of candidates gave 'oxidation' as their answer without specifying which ion had been oxidised.

(c) Most candidates gave the names or correct formulae of suitable reagents in **(i)**, and a large majority gained further credit for the unambiguous layout of the tests and observations. As candidates had been directed to use the Qualitative Analysis Notes, all should have been able to report the correct colour and solubility in excess of the iron(II) precipitates. The observations for nickel(II) with sodium hydroxide were generally excellent but a number of candidates reported a precipitate forming with $Ni^{2+}(aq)$ and $NH_3(aq)$, or that the solution turned dark blue. The test with EDTA in **(iv)** was generally performed and reported well. Many candidates gained credit for **(v)** although a substantial number expected a red-brown precipitate to be formed. Candidates obviously understood that the $Fe^{2+}(aq)$ would be oxidised but did not realise that NaOH(aq) or $NH_3(aq)$ would need to be added to form the precipitate they described.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key Messages

- Candidates should be encouraged to read each question carefully before starting to answer.
- Where two readings are required from a measuring instrument to find a quantity used, it is necessary to double the error of a single reading to find percentage error.
- Conclusions and inferences must be drawn from the actual results of tests carried out.
- Observations should be recorded in detail for each part of the instruction.

General comments

The Examiners thank 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. Those Supervisors who do not repeat titrations to ensure they are accurate may disadvantage some of their better candidates whose results may not secure the highest available credit for accuracy while still being within the tolerances for that Centre. In addition, 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 Cambridge International Examinations but this is often unobtainable and candidates may be disadvantaged as a consequence.

Almost all the candidates divided their time successfully and so completed the paper, although a very few, weaker candidates, appeared to have to rushed or omitted some of the parts of the questions.

Candidates should be encouraged to write clearly as credit cannot be given where an answer cannot be read.

Comments on specific questions

Question 1

Almost every candidate was able to complete the practical work in this question, and most gained credit in the early stages of the calculations.

(a) The weighing data and titration table were clearly laid out, although not all recorded their burette readings to 0.05 cm^3 or wrote suitable heading and units. A few candidates continued to carry out a third titration when the previous two were within 0.10 cm^3. This incurs a loss of time for answering other questions and would mean carrying out a fourth titration if the third is more than 0.10 cm^3 different from either of the other two. Most candidates were awarded some credit for accuracy with many gaining full credit.

(b) Most candidates were awarded credit here, but some did not follow the instruction to indicate which titres they were considering when calculating a mean.

(c) Parts **(i)** and **(ii)** were well answered by most candidates. However, **(iii)** proved difficult for some as the volume factor was overlooked by many, who did not divide their answer by ten. This then caused problems with part **(iv)** as the mole ratio was then approximately reversed. Candidates facing this problem tended to interchange numerator and denominator, and a substantial minority ignored the instruction to give the answer to the nearest whole number. Many candidates wrote an equation in **(v)** which followed logically from their answer to **(iv)**, so were able to gain some credit. Most candidates gave their answers to the first three parts of this question to an appropriate number of significant figures.

(d) The majority of candidates were able to give the correct percentage error for the pipette in **(i)**. However, finding the mass of **FA 1** involved two weighings, so candidates were expected to double the maximum error given for the mass of the beaker to then calculate their final answer in **(ii)**.

Question 2

Candidates found much of this question accessible and many were able to gain most or all of the available credit.

(a) Almost all candidates weighed out the required masses of **FA 4** in the two experiments. Candidates should be encouraged to lay out their data in a clear fashion with suitable headings and correct units in the tables of results. The vast majority performed the experiment accurately and were awarded full or almost full credit.

(b) The calculation of the number of moles of water removed in **(i)** and the number of moles of MX_2 was well done by most candidates. Few omitted one or more state symbol when balancing the equation in **(ii)**, and almost all the candidates balanced it correctly. Again, the majority of candidates gained the mark in **(iv)** and those completing this part generally calculated the formula mass of MX_2 correctly.

(c) Candidates needed to develop their answers further in **(i)** as few mentioned heating to constant mass. Candidates were inventive in their suggestions for cooling the contents of the crucible without the lid in **(ii)** but very few mentioned the use of a desiccator or the use of a named desiccant.

Question 3

Candidates found this question more difficult. There was a wide range of credit awarded, and some excellent answers seen where the candidates had clearly been taught the difference between observation and inference, and were able to use the correct terminology throughout. Candidates are advised to ensure that the conclusions about the identity of ions must follow the observations made. There are some candidates who confuse ‘cation’ and ‘anion’.

(a) The table for the observations of the tests in **(i)** was laid out well by most candidates, but more careful reading of the instructions leading to the inclusion of conclusions would have enabled more of them to gain credit. A number of candidates had difficulties in differentiating between a cream AgBr precipitate and AgI which is (pale) yellow. Few candidates were able to supply a correct ionic equation in **(ii)**, with many giving the half equation for the oxidation of a halide ion to a halogen. Parts **(iii)** and **(iv)** were more accessible for many. Most used their answers from **2(b)(v)** and few resorted to the default value of the formula mass of MX_2 given in the paper. Almost all remembered to multiply their halide mass by two, and used the calculated value of the A_r of M to identify the probable metal in **(iv)**. The better candidates gave the +3 charge of the cations in **(v)** to state why these metals had not been included in the list given in **(iv)**.

(b) Candidates should be given practice in tests involving negative results, and should be encouraged to think about the conclusions that can be drawn from them. A substantial number of candidates reported a white precipitate in the first part of **(i)** which meant that it was not possible for them to give the expected possible identities of the cation in **(ii)**. Correct results for the second test in **(i)** and conclusion in **(iii)** were seen more frequently. Those with incorrect results in **(i)** were not penalised in **(iv)** as candidates were able to gain credit from a logical test to distinguish between the two cations they suggested in **(ii)**. A substantial number of candidates gave the name or correct formula of a suitable reagent and reported the expected result. Many were able to carry out the tests in **(v)** successfully. Not all of these concluded that the anion was sulfate, and several cations were suggested.

CHEMISTRY

Paper 9701/41
A2 Structural Questions

Key Messages

- Candidates would benefit from an increased familiarity with skeletal formulae in multi-ring organic structures.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations clearly explaining what the numbers refer to.

General Comments

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

Candidates are reminded of the importance of reading the question carefully before they attempt an answer. Thus, **Question 1(d)** required that **state symbols** be included; **Question 2(b)(ii)** also required the **units** of the rate constant; **Question 8(a)** required a **sketch** to be included in the answer.

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

Comments on Specific Questions

Section A

Question 1

(a) (i) A number of candidates described *lattice energy* as an endothermic process here and occasional confusion with enthalpy of formation was noted from weaker candidates.

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

(b) The most common error was to suggest that the volume of oxygen would need to be measured. Most candidates gave temperature change and mass of magnesium as valid responses, whereas volume of water was less commonly seen.

(c) This calculation was completed well by the more able candidates, with others missing out terms or multipliers. The most common errors were omitting the bond energy of O_2 (or not dividing by two) or using the incorrect bond energy for O_2 (O–O instead of O=O). Candidates might have been more successful if they had drawn out the energy diagram for the process.

(d) Although this was a relatively easy equation, a large number of candidates omitted state symbols, and suggested a pH outside the allowable range.

Question 2

(a) (i) Quite a number of candidates failed to recognise that NO was a radical, and included an extra electron in their 'dot-and-cross' diagram.

(ii) Many candidates did not recognise that two moles of NO were involved, and gave –90 or +90.

(iii) Answers to this part were often too vague to be awarded credit.

(iv) Most candidates carried out this calculation successfully.

(b) (i) The explanation for the orders in the rate equation was answered well by most candidates.

(ii) Most candidates were able to give a correct equation. However, the units of k were commonly omitted.

(iii) Most candidates scored credit here. A small proportion of candidates reproduced the overall equation but forgot to actually show how it was derived. Answers to this part were often too vague to be awarded credit.

(iv) This proved to be a tricky question with only the more able candidates suggesting the correct explanation.

(c)(i)(ii) Candidates found this difficult and did not use the half-equations. $Fe(NO_3)_2$ was a common error for **(i)** and only a small number managed to give a correct balanced equation for **(ii)**.

(iii) Most candidates correctly identified the bonding as dative covalent.

(iv) This proved a more difficult question, with only the more able candidates suggesting a correct structure for this complex.

Question 3

(a) (i) Few candidates gave the correct molecular formula of indigo.

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

(b)(i)(ii) Most candidates correctly identified reduction and a suitable reagent.

(c) This question caused problems for a significant number of candidates who seemed unable to recall distinguishing tests and their observations for these functional groups. The use of Br_2 and Tollens reagent were common incorrect answers.

(d) (i) Only the more able candidates identified the correct structure of **A**.

(ii) Most candidates scored some credit here. Only a few used the correct multiplier for the moles of H_2.

(e) A small number of candidates gained full credit here. Common errors were too few or too many bromines on benzene rings. It was expected that candidates would show two bromines on each benzene ring.

Question 4

(a) (i) Candidates gave mixed answers here, some mistaking volatility for reactivity and confusing it with boiling point.

(ii) Many candidates gained full credit here, although some did not explain the reason why CCl_4 did not react with water.

(b) This question caused problems for a significant number of candidates who were unable to deduce the correct identities of **B** and **C** then write equations for the reactions described in the question stem. Common errors were unbalanced equations and omission of by-products.

Question 5

(a) (i) Most candidates correctly identified 2,4,6-tribromomethoxybenzene.

(ii) Most candidates suggested a suitable reactant and observation, although the equation proved difficult for some.

(b) (i) Most candidates correctly drew **D** as nitrobenzene, but many did not show the correct charges on **E**, the phenyldiazonium compound.

(ii) Most gained credit for Sn and HC*l* in step 2, although many omitted the use of concentrated acid and heat under reflux. Few candidates managed to identify the correct reagent and conditions for step 4.

(c) (i) This caused problems for a significant number of candidates who were unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. There were a number of poor drawings of structure here. Candidates had most difficulty with the structures of **F** and **J**, but gave correct structures of **G** and **H**.

(ii) Although stronger candidates knew the reactants and conditions for both reactions, weaker candidates omitted one or both, e.g. not mentioning the need for heat in reaction 2.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section.

Question 6

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

(ii) Many candidates performed well here.

(b) (i) Many candidates showed some knowledge of the backbone structure of DNA and correctly identified the pair basing. Inadequately labelled diagrams and ribose as the sugar were common errors.

(ii) A number of candidates correctly identified the difficulty in the separation of strands, although weaker candidates just referred to difficulty in breaking the covalent bonds.

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

(ii) A good number of candidates managed to recognise that the amount of ionic/hydrogen bonding would reduce.

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

Question 7

(a) Most candidates performed well here.

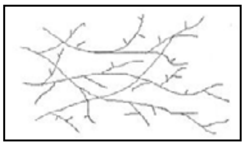
(b) (i) Candidates lost credit here for an imprecise definition of *partition coefficient*.

(ii) Most candidates scored some credit here, but only a few recognised that the pesticide would dissolve preferentially in fats/oils.

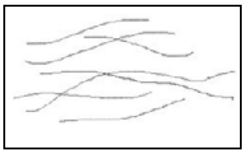
(c)(i)(ii) This question clearly divided candidates, with those who understood mass spectrometry and were able to deal with fragments often receiving full credit, whilst those who were less confident received very little credit. Many candidates did not realise that all the peaks in **(i)** were due to the molecular ions of the product of this addition, e.g. M^+ 156 $CH_3CH^{79}BrCH_2{}^{35}Cl^+$.

Question 8

(a) Many candidates did not follow the instruction in the question, to explain with the aid of sketches. Examiners were expecting a ‘simple’ sketch of the different polymers, illustrating that there is more space between chains in HDPE than LDPE.



LDPE



HDPE

(b) This was poorly answered, with only about half the candidates receiving full credit. A significant number thought that HDPE had covalent bonding between the chains instead of van der Waals’ forces.

(c) Many candidates correctly identified two differences between the methods. A common error was to describe the differences in terms of numbers of different monomers involved in the polymerisation. Candidates should be aware that there are several condensation polymers, e.g. nylon-6 and poly(lactic acid), that contain only one monomer; conversely, there are many polymers, e.g. ABS or SBR, that contain more than one monomer.

(d) (i) A good number of candidates correctly identified delocalised electrons as the mode of conduction.

(ii) This proved difficult for many candidates who could not relate this structure to the way graphite conducts electricity, i.e. that the molecule had to be planar, so that all π bonds could overlap with each other.

(iii) Many candidates were unable to deduce the empirical formula, C_4H_3, from the given repeat unit.

CHEMISTRY

Paper 9701/42
A2 Structured Questions

Key Messages

Candidates should take time to read each question thoroughly before attempting to answer it, underlining key words or phrases on the question paper to ensure they answer in the correct manner.

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

General comments

There was very little evidence of candidates running out of time, and for the most part candidates wrote clearly and legibly. It was gratifying to see good answers to even **Questions 3(c)** and **5(c)** from the best candidates. ***Section B*** also provided plenty of opportunities for candidates to demonstrate their knowledge and understanding of the applications and the responses continue to improve.

Some candidates continue to lose credit through not reading the question thoroughly enough. For example **Questions 3(a)(i)** and **8(b)(i)** asked for the **names** of functional groups, not their formulae; **Question 3(a)(ii)** asked for the observations with **both** compounds; **Question 5(a)** required the comparative acidity of ethanoic acid to be included **along with** that of the two chloroethanoic acids; **Question 7(c)(i)** asked for the **element** (phosphorus) rather than the group that contained it (phosphate).

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

Comments on specific questions

Section A

Question 1

(a) (i) A significant number of candidates confused the enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$, with that of solution, $\Delta H^{\ominus}_{sol}$, or even the enthalpy change of reaction between Mg and H_2O.

(ii) This confusion was also apparent in the equations written in **(ii)**, with

$$Mg(s) + 2H_2O \rightarrow Mg(OH)_2(aq) + H_2$$

being quite a common answer.

(iii) Most candidates correctly identified the smaller **ionic** radius of the Mg^{2+} ion (thus causing its charge density to be greater), as the reason for its larger $\Delta H^{\ominus}_{hyd}$.

(iv) Very few candidates were awarded credit here, although many would have known from their Period 2 chemistry that soluble oxides such as Na_2O dissolve in water to give the corresponding hydroxides:

$$Na_2O + H_2O \rightarrow 2NaOH$$

Thus the oxide ion does not exist in water, but reacts to give hydroxide ions.

(b) Whilst most candidates described an experiment where solid $MgCl_2$ was dissolved in water and the temperature rise noted, a significant number did not read the question carefully enough, and chose to describe a series of theoretical calculations involving lattice energies and hydration energies. It was important that the candidates stated exactly what measurements would actually be taken. So "a known number of moles of $MgCl_2$" was not adequate; " a measured **mass** of $MgCl_2$ was, however, acceptable. Likewise, "a known amount of water" was not credited, whereas "a known volume" or "100 cm^3" or "250 g of water" did score. Several mentioned taking the initial temperature, but it was not clear whether this was of the $MgCl_2$ or the water. The most common error, however, was to confuse this experiment with that for determining the solubility of $MgCl_2$. There were many descriptions of adding the solid to water, with heating, until no more dissolved. Some even described measuring the temperature rise after (external) heating had occurred.

(c) No reference was made in this question to using data from the *Data Booklet*. All data to be used in the calculations were therefore included in the table given on the question paper. Several candidates felt they needed to include *Data Booklet* values for the ionisation energies of Mg or Cl–Cl bond energy, however, and hence their answers were incorrect.

(d) This fairly straightforward piece of 'bookwork' was well answered by the majority of candidates, although some were unaware of the solubility trend of the sulfates down Group II. Many appreciated that the key thermodynamic value was that of the enthalpy change of solution, $\Delta H^\ominus_{sol}$, and that this depended largely on the relative values of the hydration energies of the ions and the lattice energies. It was important to state that both of these decreased down the group, due to the increase in cationic (**not** atomic) radius, but that the decrease in lattice energy was less than that in hydration energy.

Question 2

(a) (i) Most candidates scored credit here, although some misread the question and drew the diagram for CO_2 rather than CO. Either the double-bonded structure (with an electron deficient carbon) or the triple-bonded structure (with a dative bond from oxygen) was accepted. The most common errors were to start with too many electrons on carbon (six rather than four), or to share three electrons from each atom, resulting in an odd lone electron on carbon and three lone electrons on oxygen.

(ii) Almost all candidates scored credit here, either for stating that incomplete combustion had occurred, or that there was insufficient oxygen in the combustion chamber.

(iii) Fewer candidates were able to answer this correctly. Accepted oxidants for CO were NO or O_2. Several used NO_2 or H_2O as the oxidant, or wrote unbalanced equations.

(b) As in **Question 1(c)**, some candidates used bond energy data from the *Data Booklet* in this calculation. Several also calculated the enthalpy change for the reverse reaction.

(c) (i) Most candidates recognised this as a ligand replacement, or ligand exchange, reaction, but some omitted the 'ligand'. Others thought that it was an example of a redox reaction.

(ii) Although the first part of the explanation required here was standard bookwork, quite a number of candidates did not describe the splitting of the d-orbitals by the ligand field, the promotion of an electron from a lower to a higher level by the absorption of visible light, and the colour transmitted (**not** emitted) being the complement of the colour absorbed. For the second part, it was expected that candidates would explain that different ligands split the d-orbitals by different amounts, and so, from the relationship E = hf, the frequency (or wavelength) of light absorbed, and hence the colour transmitted, will depend on the ligand.

(iii) This part was well answered by the majority of candidates. The data needed a careful analysis, since the orders were not obvious at first glance. Taking the first and last rows in the table, and comparing the rates to the concentrations of the complex, it could be seen that as [complex] doubles, so does the rate. Thus they are proportional to each other, and so the order with respect to [complex] is one. This could be confirmed by comparing rows one and two. The fact that (CO) seems to have no effect on the rate indicates that the order with respect to (CO) is zero. Some candidates who got this far unfortunately did not finish off their argument by writing a rate equation for the reaction, as asked for in the question, and so lost credit.

(iv) This part was marked consequentially from the candidate's answer to part **(ii)**. Thus, although the correct answer is mechanism 2, because (CO) does not appear in the rate equation, if the candidate thought the reaction was first order in each reactant, either mechanism 1 or mechanism 3 would be consistent with those orders, so credit could be awarded.

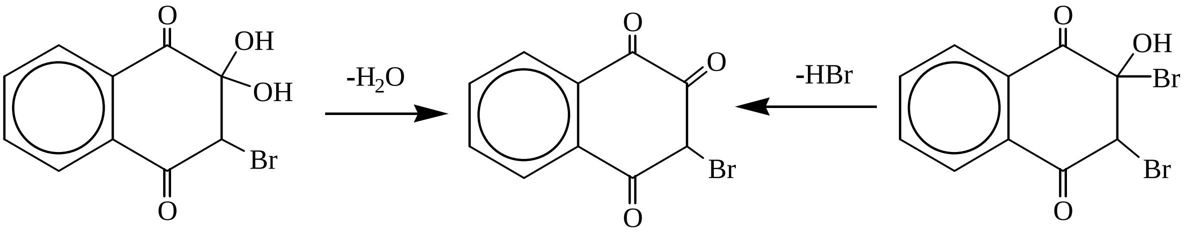
Question 3

(a) (i) It was expected that the names quoted here would be for the specific functional groups ketone, alcohol and alkene (arene was also accepted). Most gained credit here, although some stated more general groups such as carbonyl or hydroxy or double bond. Most candidates scored well, although some chose to give the group structures rather than their names.

(ii) Most candidates chose 2,4-dinitrophenylhydrazine (Brady's) as their reagent, with lawsone giving an orange (**not** yellow) precipitate and compound **A** not reacting. Several candidates suggested that lawsone would produce an orange *colour*, rather than precipitate with the reagents, indicating that perhaps they had never carried out this test in the laboratory (the reagent itself is yellow-orange in colour). Another popular reagent was $FeCl_3$ (aqueous or 'neutral' were accepted, but anhydrous was not), which would give a violet colouration (**not** precipitate) with compound **A**, a phenol, but not with lawsone. Bromine water (**not** liquid, and not with a Lewis acid catalyst) was suggested by several candidates. Both lawsone and compound **A** would decolourise the reagent, but compound **A** would be expected to give a white precipitate.

(iii) Suitable reducing agents that were accepted included $NaBH_4$ or $LiAlH_4$, or a reducing agent chosen from the $E^{\ominus}$ list in the *Data Booklet* whose $E^{\ominus}$ was more negative than 0.2 V, e.g. SO_2. Hydrogen over a catalyst was not accepted, as this would be likely to reduce the aryl rings of compound **A** as well.

(iv) Credit was available here for the structure resulting from the addition of Br_2, or HOBr, to the double bond. Bromine would not substitute in the aryl ring, as no activating group is present. Allowance was made for the fact that some candidates might be aware that a Br or OH group on the same carbon as an OH group which is already there would be unstable, and eliminate HBr (or H_2O) to give the ketone. Any of the following structures was therefore acceptable.



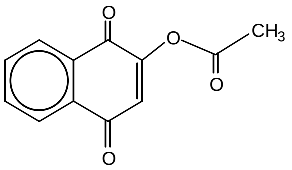
(b) (i) Most candidates correctly calculated the $E^{\ominus}_{cell}$ as +0.97 V, although some merely stated the $E^{\ominus}$ for the $Cr_2O_7^{2-}/Cr^{3+}$ electrode.

(ii) Only a minority of candidates scored full credit for this equation. Many did not incorporate the dichromate(VI) ion, or left the equation unbalanced. From the two half equations, it could be seen that the **A** : $Cr_2O_7^{2-}$ ratio needs to be 3 : 1, so the equation is:

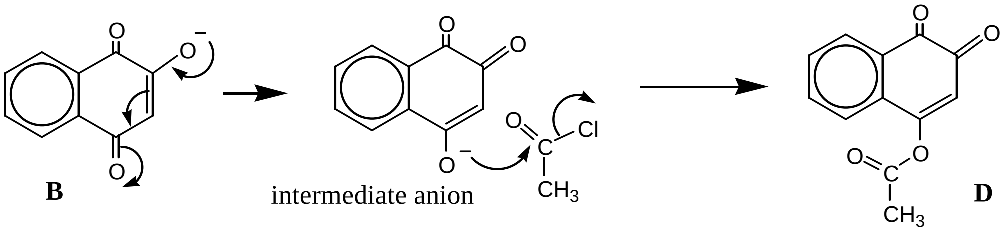
$$Cr_2O_7^{2-} + 8H^+ + 3C_{10}H_8O_3 \rightarrow 2Cr^{3+} + 7H_2O + 3C_{10}H_6O_3$$

(iii) The calculation was performed well by many candidates. The answer depended on the **A** : $Cr_2O_7^{2-}$ ratio, and was thus marked accordingly, with error-carried-forward awarded where appropriate. Common errors included not using the ratio from the equation (despite the equation having been written correctly), losing a power of 10 during the calculation, or inverting the 1000/20 ratio to convert from moles in 20 cm^3 to mol dm^{-3}.

(c) (i) This was the most straightforward question in part **(c)**, and many candidates scored credit here, for the following structure.



(ii)(iii) Only the more able candidates appreciated that the anion **B** is delocalised, such that the bottom oxygen atom experiences the negative charge too, and so could be acylated:



Question 4

(a) Most candidates scored well here, knowing that the volatilities decrease down the group due to greater van der Waals' forces. But several ascribed this to the greater molecular mass, rather than the greater number of electrons. Others predicted that the volatilities would increase, because the bond strengths decrease, showing some confusion between the concepts of volatility and reactivity.

(b) Some candidates answered this question very well, whilst others showed some confusion as to what was happening when compounds boil. Several thought that bonds were being broken within molecules, rather than intermolecular attractions being overcome.

(i) Many scored credit for 'hydrogen bonding' in water, but did not provide adequate diagrams, the $\delta+$ and $\delta-$ of the H–O– bonds needed to be shown, with the lone pair on oxygen made clear.

(ii) The permanent dipole in CH_3OCH_3 means that it has a higher boiling point than propane. Some candidates did not appreciate that the C–O–C angle in $CH_3–O–CH_3$ is not 180°, so did not recognise that the molecule would have a dipole moment. Many who identified the lone pair on the oxygen atom then suggested that hydrogen bonding occurred between that and the C–H hydrogens.

(c) Most candidates scored credit here for 'octahedral', or a suitably clear diagram. Some thought the molecule was planar. However, only a minority went on to *explain* the shape, in terms of six bond pairs and zero lone pairs.

Question 5

(a) This was well answered by many candidates, who recognised that the electronegative (electron withdrawing) chlorine atoms would weaken the O–H bond and stabilise the resulting anion, thus causing the acidity to increase from CH_3CO_2H to $CHClCO_2H$ to $CHCl_2CO_2H$.

(b) The stem of the question asked for a chemical test, with reagents and conditions. There were several alternatives for each pair of compounds. The following were accepted:

- For the cyclohexylamine-phenylamine pair, the most popular reagent was $Br_2(aq)$, which would be unchanged by cyclohexylamine but would be decolourised (with the production of a white precipitate) by phenylamine. An alternative was to add HNO_2 followed by phenol in alkaline solution, producing a yellow-red precipitated dye with phenylamine but nothing with cyclohexylamine.

- For the propanoyl chloride-chloropropanone pair, the most popular reagent was water, or an alcohol or a phenol, with the subsequent identification of the steamy fumes of HCl with propanoyl chloride. If the observation was given as "sweet ester smell produced", an alkali was needed to neutralise the HCl. Also quite popular was the use of 2,4-DNPH, which would give an orange precipitate with chloropropanone. $AgNO_3(aq)$ was also accepted (an immediate precipitate with propanoyl chloride, but much slower with chloropropanone), but was rarely seen. A fourth reagent, offered by quite a number of candidates, was aqueous alkaline iodine, which would give iodoform with chloropropanone.
- The iodoform reaction was also used here by many candidates, to distinguish between propanal and propanone. All other acceptable reagents were oxidising agents, employed to oxidise propanal: Fehling's solution; Tollens' reagent; acidified dichromate(VI); acidified manganate(VII). All of these require heating. The first two should have been described as giving precipitates (red, and silver or black, respectively); the third as changing from orange to green, and the fourth as changing from purple to colourless. Quite a number of candidates confused the results of the Fehling's and Tollens' tests.

(c) (i) Condensation was the only acceptable answer here. A significant number of candidates thought it was an example of addition polymerisation.

(ii) It was expected that candidates would recognise the ester bonds in the polymer, split the molecule at those, and hence realise that 1,4-benzenediol and heptane-1,7-dioic acid were the two monomers.

(iii) Most candidates did not score credit here, because they seemed to have forgotten that simple esterification, using heat and concentrated sulfuric acid, cannot be carried out with phenols. The diacid had to be converted into its diacyl chloride, and the diphenol into its disodium salt.

(iv) Many candidates appreciated that the long chain of the diacid needed to be shortened, or made more rigid. Quite a number of creative alternatives were seen: butane-, propane- and even ethane-dioic acids were amongst those which scored, along with the ring diacids benzene-1,4-dioic acid and cyclohexane-1,4-dioic acid. An alternative approach was to encourage cross-linking through the use of a trifunctional compound: trihdroxybenzene and tricarboxylic acids were both seen. A number chose to replace the diphenol with an aryl diamine (possibly thinking of kevlar) but ignoring the floppy aliphatic chain in the diacid.

Question 6

(a) This straightforward question was well answered by most candidates. Whilst tertiary interactions in alanine are only van der Waals', cysteine can form disulfide bridges (errors included 'sulfide', 'disulfite', and 'disulfate' bridges), lysine can hydrogen-bond or form ionic bonds with anionic groups and serine can form hydrogen bonds.

(b) Most candidates knew of the role that iron plays in haemoglobin, to transport oxygen around the body in the bloodstream. Many also were aware of the role of potassium ions in controlling nerve impulse, or the sodium-potassium pump to control ion flow into and out of cells. The role of zinc as a cofactor in enzymes, specifically carbonic anhydrase, was also known by many.

(c) (i) The compound referred to was ATP. Although many scored credit here, several others lost it by not including water in their equation: $ATP + H_2O \rightarrow ADP + Pi$.

(ii) The expected answer was hydrolysis, but since there were several ways of categorising this reaction, the following were also accepted: reversible, exothermic, nucleophilic substitution.

(d) (i) The ions Na^+ and K^+ are involved in the ion flow. Cl^- is also involved. Several candidates did not appreciate the role of K^+ here.

(ii) Hydrogen bonding, between water molecules and the mucus molecules was the expected answer. Several candidates mentioned other intermolecular attractions, such as van der Waals' or ionic, or even covalent.

Question 7

In general, answers to this question tended to be either very good, from candidates who were familiar with NMR, or quite poor, from candidates who resorted to an amount of guesswork.

(a) (i)(ii) The energy required for the promotion of the magnetic spin state depends on both local intramolecular factors, and the external magnetic environment. Quite a number of candidates thought temperature or light would affect the energy required, or how fast the proton was spinning.

(b) (i) Several candidates did not seem to relate the single peaks, with their integration values of 9 : 1, to the molecular formula given in the question. Thus of the ten hydrogen atoms in $C_4H_{10}O$, nine are equivalent to each other, and one is not. $(CH_3)_3C–OH$ fits the bill well.

(ii) There are three other alcohols with the molecular formula $C_4H_{10}O$: butan-1-ol (five groups of peaks); butan-2-ol (five groups of peaks); and 2-methylpropan-1-ol (four groups of peaks), of which the second can exist as two optical isomers. Any two of these four structures were acceptable. Even if the isomers were incorrect, credit could still be obtained by correctly identifying the number of groups or peaks in each one.

(c) (i) A significant number of candidates chose sulfur as their element here, despite the fact that nucleic acids do not contain sulfur. Perhaps this was as a result of confusion with proteins. Others wrote ‘phosphate’, the group, rather than ‘phosphorus’, the element. Most knew that the high electron density would be responsible for phosphorus to show up the most strongly of all elements present.

(ii) Likewise, it is the lack of electron density that causes hydrogen atoms not to show up. Several candidates stated that there were *no* electrons around hydrogen in its compounds.

Question 8

(a) (i) Most candidates scored well, realising that the hydrophilic moisturiser would be attracted to the ring of ionic phosphate ‘heads’ around the inner wall of the liposome, at **C**, whereas the fat-soluble vitamin would prefer to be embedded in the hydrocarbon ‘tails’ within the wall.

(ii) Area **A**, outside the liposome, would expose the molecule to (air) oxidation, or hydrolysis, or enzymatic attack. Many candidates chose the right area here, but fewer suggested an adequate reason why it would not be an appropriate place.

(b) (i) Candidates were on firmer ground here, with many suggesting amide or peptide or ester.

(ii) Hydrolysis was the required answer, and was given by many candidates. Oxidation, reduction and addition were some incorrect responses.

(iii) Although many candidates scored well in parts **(i)** and **(ii)**, there were fewer who managed to recognise the amide and ester bonds in the structure of *Sirolimus*. Despite the word **bonds** being in bold in the question, many candidates insisted on circling *atom centres* rather than bonds, or circling whole groups which might have contained 5 or 6 bonds.

(c) (i) ‘Very small but very important’ or ‘smaller than the naked eye can see’ were common responses, but not adequate for credit. An actual size, from 1 to 1000 nanometres, was expected.

(ii) Most candidates recognised that the reactive bits of the PEG molecule are the –OH groups at each end.

(iii) It was expected that candidates would recognise the hydrophilic nature of the PEG molecule as a result of the hydrogen-bonding capabilities of the many oxygen atoms, situated at every third atom of the chain, and the OH group at the end of the chain.

CHEMISTRY

Paper 9701/43
A2 Structural Questions

Key Messages

- Candidates would benefit from an increased familiarity with skeletal formulae in multi-ring organic structures.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations clearly explaining what the numbers refer to.

General Comments

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

Candidates are reminded of the importance of reading the question carefully before they attempt an answer. Thus, **Question 1(d)** required that **state symbols** be included; **Question 2(b)(ii)** also required the **units** of the rate constant; **Question 8(a)** required a **sketch** to be included in the answer.

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

Comments on Specific Questions

Section A

Question 1

(a) (i) A number of candidates described *lattice energy* as an endothermic process here and occasional confusion with enthalpy of formation was noted from weaker candidates.

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

(b) The most common error was to suggest that the volume of oxygen would need to be measured. Most candidates gave temperature change and mass of magnesium as valid responses, whereas volume of water was less commonly seen.

(c) This calculation was completed well by the more able candidates, with others missing out terms or multipliers. The most common errors were omitting the bond energy of O_2 (or not dividing by two) or using the incorrect bond energy for O_2 (O–O instead of O=O). Candidates might have been more successful if they had drawn out the energy diagram for the process.

(d) Although this was a relatively easy equation, a large number of candidates omitted state symbols, and suggested a pH outside the allowable range.

Question 2

(a) (i) Quite a number of candidates failed to recognise that NO was a radical, and included an extra electron in their 'dot-and-cross' diagram.

(ii) Many candidates did not recognise that two moles of NO were involved, and gave –90 or +90.

(iii) Answers to this part were often too vague to be awarded credit.

(iv) Most candidates carried out this calculation successfully.

(b) (i) The explanation for the orders in the rate equation was answered well by most candidates.

(ii) Most candidates were able to give a correct equation. However, the units of k were commonly omitted.

(iii) Most candidates scored credit here. A small proportion of candidates reproduced the overall equation but forgot to actually show how it was derived. Answers to this part were often too vague to be awarded credit.

(iv) This proved to be a tricky question with only the more able candidates suggesting the correct explanation.

(c)(i)(ii) Candidates found this difficult and did not use the half-equations. $Fe(NO_3)_2$ was a common error for **(i)** and only a small number managed to give a correct balanced equation for **(ii)**.

(iii) Most candidates correctly identified the bonding as dative covalent.

(iv) This proved a more difficult question, with only the more able candidates suggesting a correct structure for this complex.

Question 3

(a) (i) Few candidates gave the correct molecular formula of indigo.

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

(b)(i)(ii) Most candidates correctly identified reduction and a suitable reagent.

(c) This question caused problems for a significant number of candidates who seemed unable to recall distinguishing tests and their observations for these functional groups. The use of Br_2 and Tollens reagent were common incorrect answers.

(d) (i) Only the more able candidates identified the correct structure of **A**.

(ii) Most candidates scored some credit here. Only a few used the correct multiplier for the moles of H_2.

(e) A small number of candidates gained full credit here. Common errors were too few or too many bromines on benzene rings. It was expected that candidates would show two bromines on each benzene ring.

Question 4

(a) (i) Candidates gave mixed answers here, some mistaking volatility for reactivity and confusing it with boiling point.

(ii) Many candidates gained full credit here, although some did not explain the reason why CCl_4 did not react with water.

(b) This question caused problems for a significant number of candidates who were unable to deduce the correct identities of **B** and **C** then write equations for the reactions described in the question stem. Common errors were unbalanced equations and omission of by-products.

Question 5

(a) (i) Most candidates correctly identified 2,4,6-tribromomethoxybenzene.

(ii) Most candidates suggested a suitable reactant and observation, although the equation proved difficult for some.

(b) (i) Most candidates correctly drew **D** as nitrobenzene, but many did not show the correct charges on **E**, the phenyldiazonium compound.

(ii) Most gained credit for Sn and HCl in step 2, although many omitted the use of concentrated acid and heat under reflux. Few candidates managed to identify the correct reagent and conditions for step 4.

(c) (i) This caused problems for a significant number of candidates who were unable to draw upon knowledge from a range of areas of the organic chemistry syllabus. There were a number of poor drawings of structure here. Candidates had most difficulty with the structures of **F** and **J**, but gave correct structures of **G** and **H**.

(ii) Although stronger candidates knew the reactants and conditions for both reactions, weaker candidates omitted one or both, e.g. not mentioning the need for heat in reaction 2.

Section B

Overall, many candidates made a very satisfactory attempt at the questions in this section.

Question 6

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

(ii) Many candidates performed well here.

(b) (i) Many candidates showed some knowledge of the backbone structure of DNA and correctly identified the pair basing. Inadequately labelled diagrams and ribose as the sugar were common errors.

(ii) A number of candidates correctly identified the difficulty in the separation of strands, although weaker candidates just referred to difficulty in breaking the covalent bonds.

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

(ii) A good number of candidates managed to recognise that the amount of ionic/hydrogen bonding would reduce.

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

Question 7

(a) Most candidates performed well here.

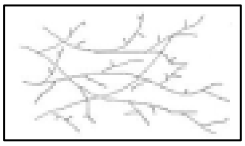
(b) (i) Candidates lost credit here for an imprecise definition of *partition coefficient*.

(ii) Most candidates scored some credit here, but only a few recognised that the pesticide would dissolve preferentially in fats/oils.

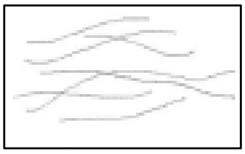
(c)(i)(ii) This question clearly divided candidates, with those who understood mass spectrometry and were able to deal with fragments often receiving full credit, whilst those who were less confident received very little credit. Many candidates did not realise that all the peaks in **(i)** were due to the molecular ions of the product of this addition, e.g. M^+ 156 $CH_3CH^{79}BrCH_2{}^{35}Cl^+$.

Question 8

(a) Many candidates did not follow the instruction in the question, to explain <u>with the aid of sketches</u>. Examiners were expecting a 'simple' sketch of the different polymers, illustrating that there is more space between chains in HDPE than LDPE.



LDPE



HDPE

(b) This was poorly answered, with only about half the candidates receiving full credit. A significant number thought that HDPE had covalent bonding between the chains instead of van der Waals' forces.

(c) Many candidates correctly identified two differences between the methods. A common error was to describe the differences in terms of numbers of different monomers involved in the polymerisation. Candidates should be aware that there are several condensation polymers, e.g. nylon-6 and poly(lactic acid), that contain only one monomer; conversely, there are many polymers, e.g. ABS or SBR, that contain more than one monomer.

(d) (i) A good number of candidates correctly identified delocalised electrons as the mode of conduction.

(ii) This proved difficult for many candidates who could not relate this structure to the way graphite conducts electricity, i.e. that the molecule had to be planar, so that all π bonds could overlap with each other.

(iii) Many candidates were unable to deduce the empirical formula, C_4H_3, from the given repeat unit.

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

This examination followed the usual format.

Candidates should realise that when a sketch graph is required this does not imply that carelessly drawn lines are acceptable. As much precision as possible should be shown. Straight lines should be drawn using a ruler and not freehand and as many reference points as possible should be included.

When questions ask for descriptions of laboratory experiments candidates should focus on the specific points asked for in the stem of the question. Specific points were asked for in **Question 1(c)** but were often missing from candidates' explanations.

Many candidates lost credit through a lack of thought about sensible scales and a lack of precision when drawing graphs. In one response to **Question 2**, a scale of ten small squares to represent 1.12 cm^3 on the *y*-axis and 17.1111 K on the *x*-axis was chosen. Sharp pencils are essential to plot points accurately, preferably as a small cross, and straight lines can only be drawn with the aid of a ruler; these lines should be straight, single and with no kinks or slight changes of gradient.

Comments on specific questions

Question 1

(a) Most candidates realised that the moles of copper hydroxide increased as the concentration of copper sulfate solution increased, and were able to produce a sketch graph with a straight line of positive gradient from the origin. Fewer candidates realised that the line had to terminate at the saturation concentration of copper sulfate solution. Candidates received credit for marking the co-ordinates of this point on their sketch.

(b) The independent and dependent variables were usually correctly identified.

(c) Most candidates suggested that a minimum of five different concentrations of copper sulfate were required in this investigation but many had difficulty in suggesting an appropriate range. Impossible concentrations of greater than 1.39 mol dm^{-3} were often suggested. The techniques of filtration, drying and weighing the precipitate were often correctly described. Candidates do need to suggest how the drying process is carried out. A simple statement such as "the precipitate was left to dry" would not receive credit and, in this case, direct heating of copper hydroxide would have caused its decomposition. A common error in calculating the concentration of one of the solutions was to ignore the five molecules of water of crystallisation in copper sulfate crystals. Additionally, many candidates added a mass of copper sulfate to 100 cm^3 of water to make a solution, rather than by dissolving the salt in water and making up to 100 cm^3 solution.

(d) Credit was given for recognising that the sodium hydroxide solution was, at 2.0 mol dm^{-3}, corrosive and that copper sulfate was an irritant or harmful to the environment. More precision is needed when giving precautions. Various types of gloves are available in laboratories and in this case a good answer would have been chemically-resistant gloves.

(e) Answers to this question were generally good. Occasionally credit was lost when units were omitted or incorrectly written in column headings.

Question 2

(a) Generally the table was completed well. Credit was occasionally lost when (A + 273) and/or (B + 26) was omitted from the column headings. Some candidates do not understand the concept of three significant figures.

(b) Most candidates correctly plotted volume on the *y*-axis and absolute temperature on the *x*-axis. Some realised that the true origin was a sensible point to plot but, in this particular case, candidates who did not do so were not penalised. Comments have already been made about the choice of scales and the quality of plotting and drawing of lines.

(c) Correctly plotted graphs revealed two clearly anomalous points and, whilst these were often correctly identified, candidates found it difficult to suggest explanations. Expected answers were low recorded volume because the gas had not reached equilibrium with an increased temperature, and high recorded volume because the gas had not reached equilibrium with a decreased temperature.

(d) Many good answers were seen. Where there were errors, candidates had misread intercepts and/or had inverted the expression for the gradient of the line. Most candidates obtained a volume at 273 K by simply reading a value from their graph. This was the expected approach. Candidates who realised that the line started at the true origin and calculated a value received credit.

(e) The expected answer here was that the results were reliable because most of the points were on the line. ‘Few anomalies’ was also an acceptable answer.

(f) A number of candidates tried to answer this by starting with a statement of Charles’s Law. The expected approach was to state that as the results produced a straight line, volume is directly proportional to absolute temperature.

(g) Very few correct answers were seen here. Most attempts featured a straight line above the original, but parallel to it. The expected answer was a straight line of steeper gradient than the original drawn so that it appeared not to intersect the original above 0 K.

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

This examination followed the usual format. The paper successfully identified those candidates with high level practical and graphical skills.

In **Question 1** the diagram required the successive collection of two different products which many candidates found challenging. The stem of the question provided four bullet point prompts to expected responses which candidates should be advised to address in their responses.

In **Question 2**, two points about data tables are common every session. Firstly, candidates need to fully label each new column used. Secondly, the data needs to be correctly quoted to a specified number of either decimal places or significant figures. In this examination, the data requirement was for three significant figures. There was evidence that some candidates wrongly believe that the number of decimal places is the same as significant figures. Candidates should be advised to check the required number of significant figures / decimal places before calculating any data.

The non ideality of the gas, which was an important feature of this question, was not always recognised.

Comments on specific questions

Question 1

(a) The intent of this question was to understand the stochiometric relationships given in the equation of the reaction and to apply it in two different circumstances. The information given in the question needed to be carefully considered before an answer was attempted. For example, both parts required a quantitative response rather than a qualitative one.

(i) Most candidates indicated an increase in the number of moles of nitrogen(I) oxide as the number of moles of ammonium nitrate(V) increased. This was expressed in a variety of acceptable ways such as proportionality. Many answered quantitatively and gave the correct 1 : 1 molar ratio, again expressed in a number of ways, e.g. doubling the moles of nitrate will double the moles of gas.

(ii) Again most candidates gave a qualitative response and fewer a quantitative 1 : 3 ratio. The stem of the question required the sum of the number of moles of gas, and whilst most recognised that at 110 °C steam would be a gas, many gave separate ratios for each gas rather than a sum. A few candidates gave over complicated responses that involved energetics, reaction rates or equilibrium shifts rather than the simpler stochiometric direction of the question.

(iii) The requirement of the sketch graph was to graphically illustrate the prediction made earlier. The axes of a sketch graph always need to be labelled as requested in the stem of the question. It is always advisable to label the *x*-axis as the independent variable and the *y*-axis with the dependent variable which in this case were the number of moles of NH_4NO_3 and moles (of product) respectively. Some candidates had these inverted and others had temperature as one of the labels. The prediction in part **(i)** of a straight line of positive gradient with no plateau was given by many, but a second line of greater slope for part **(ii)** was less common.

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

(c) An essential precursor to drawing a suitable diagram is to decide on how to proceed with the task. The requirement was to heat a sample then separately collect the two products and, as required by part **(a)(i)**, measure the quantity of nitrogen(I) oxide. Most candidates realised that direct heating was necessary in order to decompose the ammonium nitrate(V), although many were distracted by the 25 °C (which was intended to relate to the physical state of the products not the temperature of the decomposition) and used water baths, sometimes thermostatically controlled. The majority of candidates had good ideas for condensing the steam and collecting the nitrogen(I) oxide, but more thought was needed for the collection of the condensed water and how the separate parts should be put together. The essential point of this apparatus was that the two products needed to be collected separately in sequence with the condensed water first. Many candidates had two separate outputs from the heating vessel to two separate collectors, both of which would collect both products. Some who chose to use a Liebig or ice condenser had an output for water which was open to the atmosphere such that, even if there was a subsequent gas collector in train, it would not have collected gas which would have escaped in the earlier part of the apparatus. The capacity of the gas collector was needed, but this was often omitted.

(d) There was variable use made of the bullet points provided. The most successful responses closely followed these points, often with bullet points addressing each point one at a time. In this type of assessment it is usual to specify a minimum number of experiments to produce a reasonable graph and also a range of volume that would do the same, as well as not exceeding the collector capacity. A reasonable range would cover most of the collector capacity whilst avoiding its extremes. Credit for these points was sometimes gained in the table in **(f)**. Mass calculations when started were sometimes incomplete and did not have a volume or a mass. Care was needed using when 24.0 dm^3 and converting to cm^3.

It was acceptable to round calculated figures, e.g. 0.1666….. to 0.167 or 0.17, but not to truncate to 0.16. In the final point the requirement was for a positive observation of the reaction end such as ‘the syringe piston stops moving’ or ‘bubbles from the delivery tube have stopped’. Many candidates were successful here whilst others provided a deduction such as ‘gas production has ceased’ rather than an observation.

(e) The provision of hazcard data may have confused some candidates in that combustible was often given as a hazard of ammonium nitrate(V). The question required a hazard to be coupled with a reasonable precaution to combat the hazard. Another hazard was hot apparatus which needed to be handled with heatproof gloves or appropriate holders. A significant minority erroneously gave nitrogen(I) oxide as poisonous.

(f) Many candidates gave the four required column headings complete with their units properly presented. Often other quantities such as temperature were included, and some required columns were missing. In responding here, candidates should consider the derived quantities that are necessary to construct the graph that is required, and then work back to their precursors and include them in the table. Most candidates included correct units.

Question 2

There as a great deal of significant information in this question prior to part **(a)**. In this question it was important to realise that the carbon dioxide gas does not always behave as an ideal gas. This non-ideality had a significant impact on the remaining questions. Candidates should be encouraged to read this text preceding the remaining questions since the information is required for correct responses.

(a) There were two common errors in headings and data that occured regularly.

Each column heading needs three things, a description, e.g. PxV, a unit, e.g. /kPacm^3 and an expression to calculate the data, e.g. A × B as required. Very often one of these was missing. Most candidates did calculate the required PV and 1/V columns.

Also stated was a requirement for a specific number of significant figures. There was a general misunderstanding of the difference between significant figures, decimal places and also trailing zeros. In this case the requirement was for three significant figures in all data. Most candidates in this examination successfully quoted the data to three significant figures including proper use of trailing zeros, e.g. 0.0370. Some candidates recorded 1/V values to three decimal places (0.092) rather than three significant figures (0.0917). There was also some evidence of truncation of data rather than correct rounding.

The units used in the two data columns were kPa and cm^3. Some candidates apparently changed these to Pa and/or m^3 in their calculated columns. Whilst this is acceptable it does add another layer of calculation which may introduce error especially with the 10^6 factor in volume, and can introduce errors in slope calculations where changing intercepts from kPa to Pa was not always explained. Many candidates presented their data in standard form which, again, is acceptable provided it is done correctly. For example, all of the PV values in the table could be given as 3.05×10^3, etc. under a column heading of PV/kPa cm^3. However, if the values in the table were given as 3.05, etc. the column heading needed to be PV × 10^{-3}/kPa cm^3 or PV/10^3 kPa cm^3. Ensuring that these headings are correct is difficult. Further these values/units need to be transferred to the graph axes and the slope calculation. It is common to find these factors of ten missing in slope calculations. Candidates should be advised not to overcomplicate their calculations with operations and unit changes that are not necessary.

(b) The given graph of V against P was intended in part to show the candidate that there was one anomalous result and which it was. The PV against P plot, excluding the anomaly, gives a curve sloping downwards at high pressure which was intended to demonstrate the non ideality of the gas at high pressures. Most candidates incorrectly gave a straight line for this plot. As a consequence the graph given in part **(c)** was usually a straight line of ideality.

(c) When plotting data the first consideration is to identify the independent variable and assign it to the *x*-axis. In this case the independent variable was pressure which most candidates correctly identified. Also the axes were usually well labelled with the correct unit and most candidates chose reasonable scales that were straightforward to plot and check. Some candidates chose non-linear scales (0.10 – 0.20) at the top of the 1/V scale and the top point at 0.110 on 1/V was sometimes incorrectly plotted at 0.101. Most candidates drew a straight line rather than a line which curved upwards after a pressure of around 200 kPa. The stem of the question advised the candidates to begin the scales on both axes at 0, which was generally done but this did not prompt some candidates to draw their line into the origin.

(d) If correctly plotted there was one anomalous value at point 7, but if a straight line was drawn the candidate could correctly specify more including point 1 at the top which would have been the most anomalous in that situation. Very few candidates gave a reasonable explanation for their anomalies.

(e) As the gas is non-ideal, the requirement for the slope had to be at low pressure which was in the initial (linear) part of the graph which had to start at the origin, so constructions had to be in that part of the graph. Whilst most candidates gave correct intercepts some gave table points with no graphical constructions. Those who used standard form in their data needed to carry that through in their values. Some candidates at this stage changed to Pa from kPa without any explanation of that change.

(f) The correct response here in part **(i)** and **(ii)** again referred to the initial slope of the graph and that initially the line was both straight and from the origin following a $y = mx$ pattern. Some candidates stated that most points were on the line of best fit, which was a comment on the reliability of the data rather than its confirmation of Boyle's Law. In part **(iii)** the requirement was that the V against P plot as a curve with varying gradient cannot be used to verify a straight line relationship, it is necessary to have a straight line.

(g) Again the question referred to the initial slope of the graph as an area where the slope is constant or the gas behaviour approximates to ideality. Most responses centred on the slope confirming Boyle's Law without reference to the qualities of the slope. In part **(ii)** only a few candidates realised that the value of the slope was the reciprocal of the Boyle's Law constant.

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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

This examination followed the usual format.

Candidates should realise that when a sketch graph is required this does not imply that carelessly drawn lines are acceptable. As much precision as possible should be shown. Straight lines should be drawn using a ruler and not freehand and as many reference points as possible should be included.

When questions ask for descriptions of laboratory experiments candidates should focus on the specific points asked for in the stem of the question. Specific points were asked for in **Question 1(c)** but were often missing from candidates' explanations.

Many candidates lost credit through a lack of thought about sensible scales and a lack of precision when drawing graphs. In one response to **Question 2**, a scale of ten small squares to represent $1.12\,cm^3$ on the *y*-axis and 17.1111 K on the *x*-axis was chosen. Sharp pencils are essential to plot points accurately, preferably as a small cross, and straight lines can only be drawn with the aid of a ruler; these lines should be straight, single and with no kinks or slight changes of gradient.

Comments on specific questions

Question 1

(a) Most candidates realised that the moles of copper hydroxide increased as the concentration of copper sulfate solution increased, and were able to produce a sketch graph with a straight line of positive gradient from the origin. Fewer candidates realised that the line had to terminate at the saturation concentration of copper sulfate solution. Candidates received credit for marking the co-ordinates of this point on their sketch.

(b) The independent and dependent variables were usually correctly identified.

(c) Most candidates suggested that a minimum of five different concentrations of copper sulfate were required in this investigation but many had difficulty in suggesting an appropriate range. Impossible concentrations of greater than $1.39\,mol\,dm^{-3}$ were often suggested. The techniques of filtration, drying and weighing the precipitate were often correctly described. Candidates do need to suggest how the drying process is carried out. A simple statement such as "the precipitate was left to dry" would not receive credit and, in this case, direct heating of copper hydroxide would have caused its decomposition. A common error in calculating the concentration of one of the solutions was to ignore the five molecules of water of crystallisation in copper sulfate crystals. Additionally, many candidates added a mass of copper sulfate to $100\,cm^3$ of water to make a solution, rather than by dissolving the salt in water and making up to $100\,cm^3$ solution.

(d) Credit was given for recognising that the sodium hydroxide solution was, at $2.0\,mol\,dm^{-3}$, corrosive and that copper sulfate was an irritant or harmful to the environment. More precision is needed when giving precautions. Various types of gloves are available in laboratories and in this case a good answer would have been chemically-resistant gloves.

(e) Answers to this question were generally good. Occasionally credit was lost when units were omitted or incorrectly written in column headings.

Question 2

(a) Generally the table was completed well. Credit was occasionally lost when (A + 273) and/or (B + 26) was omitted from the column headings. Some candidates do not understand the concept of three significant figures.

(b) Most candidates correctly plotted volume on the *y*-axis and absolute temperature on the *x*-axis. Some realised that the true origin was a sensible point to plot but, in this particular case, candidates who did not do so were not penalised. Comments have already been made about the choice of scales and the quality of plotting and drawing of lines.

(c) Correctly plotted graphs revealed two clearly anomalous points and, whilst these were often correctly identified, candidates found it difficult to suggest explanations. Expected answers were low recorded volume because the gas had not reached equilibrium with an increased temperature, and high recorded volume because the gas had not reached equilibrium with a decreased temperature.

(d) Many good answers were seen. Where there were errors, candidates had misread intercepts and/or had inverted the expression for the gradient of the line. Most candidates obtained a volume at 273 K by simply reading a value from their graph. This was the expected approach. Candidates who realised that the line started at the true origin and calculated a value received credit.

(e) The expected answer here was that the results were reliable because most of the points were on the line. ‘Few anomalies’ was also an acceptable answer.

(f) A number of candidates tried to answer this by starting with a statement of Charles’s Law. The expected approach was to state that as the results produced a straight line, volume is directly proportional to absolute temperature.

(g) Very few correct answers were seen here. Most attempts featured a straight line above the original, but parallel to it. The expected answer was a straight line of steeper gradient than the original drawn so that it appeared not to intersect the original above 0 K.