

CHEMISTRY

Paper 9701/01 Multiple Choice
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<i>Question Number</i>	<i>Key</i>	<i>Question Number</i>	<i>Key</i>
1	A	21	C
2	C	22	D
3	D	23	D
4	C	24	C
5	D	25	D
6	C	26	C
7	B	27	C
8	D	28	B
9	A	29	D
10	D	30	C
11	A	31	B
12	B	32	A
13	D	33	D
14	C	34	B
15	C	35	C
16	A	36	C
17	D	37	B
18	D	38	D
19	D	39	B
20	D	40	B

General Comments

For this paper, the mean score was 22.2 (55.5%) and the standard deviation of the scores was 7.19 (18.0%), indicating that overall the paper performed very satisfactorily.

The first 30 questions were simple completion items: **Questions 31 to 40** were three-statement multiple completion items.

Comments on Individual Questions

Two questions, **Questions 11** and **18**, had a slightly higher facility. It is encouraging to note that the calculation of K_p values, which has given difficulty in the past, is now understood, as are the environmental hazards of certain gases.

One question, **Question 7**, had a low discrimination in distinguishing between more able and less able candidates. Candidates were asked to identify the gas which would most nearly approximate to the behaviour of an ideal gas, and whereas 52% correctly identified helium, a significant proportion, 31%, which

included some of the more able candidates, chose the diatomic hydrogen, H₂.

Six other questions, while performing satisfactorily in distinguishing between candidates, deserve comment. In each of these one of the distractors proved more popular than the key.

Question 2 was concerned with the volume changes involved in the complete combustion of CS₂(g) in an excess of oxygen, followed by the absorption of acidic gases by NaOH(aq). It is puzzling that 36% chose the distractor **B**, compared with the 33% who correctly chose the key **C**. It may be that candidates found this question too difficult: the results indicate that a high proportion, 54%, did not consider that SO₂(g) was acidic.

In considering the strength of possible hydrogen bonding between molecules in liquid hydrogen halides in **Question 5**, more candidates thought that bond dissociation energies would be a better indicator than enthalpy changes of vaporisation.

In **Question 30** in the calculation of the yield of ethyl ethanoate from equal masses of ethanol and ethanoic acid, too many candidates based their calculation on ethanol rather than on the ethanoic acid.

In **Question 32** 55% of candidates did not believe that water can act as a Bronsted-Lowry acid.

In **Question 33** 72% believed that either the enthalpy change of a reaction and/or its equilibrium constant would have an effect on the rate of its forward reaction.

Finally, in **Question 39** 56% of candidates considered that CH₃CH₂CH(CH₃)CH₂CH₃ could be a product of a termination step in the free radical bromination of propane: which two radicals from this reaction could join to give this compound?

References are given to the Learning Outcomes within each section of the Syllabus

<i>Item Number</i>	<i>Learning Outcome</i>	<i>Item Number</i>	<i>Learning Outcome</i>
1	1(h)(i)	21	10.2(d)(iii); 10.4(a)(iv)
2	1(h)(ii); 9.1(g),(h)	22	10.1(i); 10.2(b)(ii)
3	2(h)	23	9.4(f)(i); 10.3(c)
4	2(d)	24	5(f); 10.3(b)
5	3(g),(k)	25	10.4(a)(ii),(iii),(iv),(vi)
6	3(k); 4(e)(iii),(h); 10.8(a)	26	10.3(a)(i); 10.6(a),(b)(ii)
7	4(a),(b)(i)	27	10.4(a); 10.6(b)(i)
8	5(e)(i)	28	10.6(h)
9	5(b)(i),(f); 8(a)	29	10.5(b); 10.6(a)
10	7(c)	30	1(h)(i); 10.6(b)(ii)
11	7(d),(e)	31	3(g),(h),(k)
12	8(e)(i)	32	7(h)
13	9.1(h); 10.2(i)	33	8(a)
14	9.1(e),(h)	34	9.2(a),(b),(c)
15	9.1(e)	35	9.4(b)
16	9.2(a),(c)	36	7(c),(g); 9.6(c)
17	9.4(f)(ii)	37	10.2(a),(d)(iv),(g)
18	9.6(g),(h)	38	10.3(d)
19	9.6(b)	39	10.2(c)
20	10.1(i)	40	3(k); 10.2(d)(i); 10.5(d)

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Paper 9701/02

AS Structured Questions

General comments

There were many good answers to this paper which tested candidates' knowledge and understanding of some of the theoretical aspects of AS Level Chemistry. The work of a good number of candidates was exemplary, while most candidates were able to demonstrate some positive achievement.

Chemistry has a significant factual content and parts of each question asked candidates to recall knowledge. There were many good answers to these questions, but a number of candidates had not learned some basic chemistry and were penalised. This was particularly true for **Question 3** which was concerned with inorganic chemistry. Answers to **Questions 4** and **5**, which were concerned with organic chemistry, were generally well done thus maintaining the recent improvement in the standard of organic chemistry answers.

Answers to the calculations in **Questions 1** and **2** were often poorly done. Many candidates did not explain clearly the individual steps in their calculations and often ended up confusing themselves. In **Question 2(b)(ii)**, a surprising number of candidates failed to give their answers to two significant figures as the question required.

The handwriting of some candidates continues to cause Examiners some concern. This was particularly evident in some of the answers to the calculations. If an answer cannot be read, no marks can be awarded.

Comments on specific questions

Question 1

Intended as a straightforward start to the paper, this question asked candidates to apply fundamental chemical understanding in a somewhat unusual context. There were many good answers.

- (a) (i) Most candidates knew the effects of a catalyst on the rate of a reaction, but fewer explained that it lowers the activation energy or that it provides an alternative reaction pathway.
- (ii) The majority of candidates gave the following correct equation.



- (b) (i) Most candidates recognised $\text{C}_{15}\text{H}_{32}$ as an alkane.
- (ii) There were many correct answers to this calculation, one solution of which follows.

From the equation above, 1 mol of O_2 is produced from 2 mol of H_2O_2 .

From the equation given in the question paper, 23 mol of O_2 are required for the complete combustion of 1 mol of $\text{C}_{15}\text{H}_{32}$.

Thus 46 mol of H_2O_2 will provide sufficient oxygen for the complete combustion of 1 mol of $\text{C}_{15}\text{H}_{32}$.

- (c) (i) There were fewer correct answers to this part, often because candidates failed to calculate M_r for $C_{15}H_{32}$ correctly as 212. The amount of diesel fuel used is calculated as follows.

$$n(C_{15}H_{32}) = \frac{212 \times 10^6}{212} = 1 \times 10^6 \text{ mol}$$

- (ii) A significant number of candidates struggled with this part which required candidates to use their answers to (b)(ii) and (c)(i). They also had to calculate M_r for H_2O_2 correctly as 34.

Thus 46×10^6 mol of H_2O_2 will provide sufficient oxygen for the complete combustion of 1×10^6 mol of $C_{15}H_{32}$.

The mass of H_2O_2 required = $34 \times 46 \times 10^6$ g = 1564 tonnes.

- (d) Many candidates understood that the exhaust products, H_2O and CO_2 , would dissolve in the seawater.

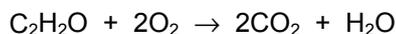
Question 2

The ability to carry out thermochemical calculations correctly is an important part of AS and A Level Chemistry. While many candidates' calculations were correct, there were also many who failed to present their answer to **part (b)(ii)** to two significant figures, or who were unable to apply Hess' Law correctly in **part (c)(ii)**.

- (a) (i) The deduction of the bond angles in ketene proved surprisingly difficult to many candidates. Using VSEPR theory, the H-C-H bond angle will be about 120° while the C=C=O bond angle will be 180° . For the former, Examiners accepted answers in the range 117° to 120° .

- (ii) Most candidates were able to suggest that the name *ketene* is derived from ketone and alkene.

- (b) (i) The majority of candidates gave the following correct equation.



- (ii) This calculation caused problems to many candidates, often due to carelessness on their part. Such calculations may be tackled in more than one way and the following answer is one of a number that are correct.

From the equation in (b)(i), $42 \text{ g } C_2H_2O \rightarrow 2 \times 24 \text{ dm}^3 \text{ of } CO_2$

$$\text{whence } 3.5 \text{ g } C_2H_2O \rightarrow \frac{2 \times 24 \times 3.5}{42} \text{ dm}^3 \text{ of } CO_2$$

$$= 4.0 \text{ dm}^3 \text{ of } CO_2$$

Answers that were not to two significant figures were penalised.

- (c) (i) Thermochemical definitions must be accurately stated, something which only a minority of candidates achieved. Common errors were to refer to 'one mole of a substance' rather than to 'one mole of a compound' and to make no reference to 'standard states' as opposed to standard conditions. A clear definition is to be found in AS and A Level Chemistry by Ratcliff et al, published by Cambridge University Press.

- (ii) Many candidates struggled with this calculation, largely because they did not use a logical method. All the data needed are given in the question, and those candidates who tried to use bond energies from the *Data Booklet* received no credit. The correct answer is calculated as follows.

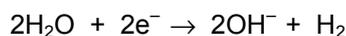
$$\Delta H = 2(-395) + (-286) - (-1028) = -48 \text{ kJ mol}^{-1}$$

- (d) A simple calculation shows that if a water molecule is 'added' to a molecule of ketene, the product will have the same molecular formula as ethanoic acid. Many candidates found this surprisingly difficult. Common wrong answers involved dichromate(VI) or manganate(VII), suggesting candidates thought they were being asked for the reagent for a reaction.

Question 3

The chemistry of chlorine and its compounds is a very important part of AS Level Chemistry. Much of the chemistry involved is factual and must be learned. Sadly, a significant number of candidates had failed to do this and many candidates scored low marks on this question.

- (a) The majority of candidates wrote correct half-equations. Fewer gave correct state symbols. Common errors were to state that sodium metal or chlorine will be liberated at the cathode.
- (b) The majority of candidates understood that if steel were used as the anode it would react with the chlorine produced. A small number of candidates thought steel reacted with chloride ions.
- (c) (i) Many candidates knew that NaOH will remain in solution in the diaphragm cell.
- (ii) On the other hand, very few were able to give a clear explanation of how Na^+ and OH^- ions are left in solution. Only a minority gave a relevant half-equation such as the following.



- (d) Examiners expect candidates to be able to describe what they see when many of the common reactions of AS and A Level Chemistry, such as the two in this question, are carried out. While there were many correct equations, there were fewer accurate descriptions.
- (e) The different effects of water on the chlorides of the elements of the third period are an important aspect of the study of chemical periodicity. Only about half of all candidates knew the value of the pH of each of the two solutions formed, while fewer were able to explain what happens in each case.

Question 4

This question tested some basic organic chemistry from a slightly unusual viewpoint. It was generally well-answered.

There were more correct answers to the 'type of reaction' column than there were to the 'reagent(s)' column.

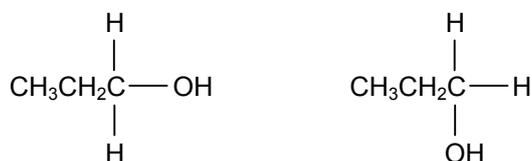
Some candidates were clearly guessing or 'hedging their bets' by giving two very different and contradictory answers and were often penalised as a result. A good example of this was in the reagents for the very last reaction,



Many candidates correctly viewed this as an oxidation and some then suggested two oxidising agents – cold, dilute, acidified, manganate(VII) ions, which will give the diol, and acidified dichromate(VI) ions which will not. Examiners regarded such answers as contradictory and awarded no credit.

Question 5

Understanding the three-dimensional nature of molecules is demanding of candidates but many produced very clear diagrams of the required structures. There remains, however, a significant number who do not understand that the following two molecules are identical.



The use of simple molecular models greatly assists the teaching of this difficult topic.

- (a) Most candidates were able to determine the correct molecular formula for **B** which was $C_4H_8O_2$.
- (b) There were many candidates who gave the three correct structures given below.



However, only a minority were able to deduce the fourth structure which was as follows.



The most common error was to give the same structure twice although a surprising number of candidates did not appear to know the structure of the ester group.

- (c) (i) Very few candidates were unable to state that compound **D** must contain a carbonyl group.
- (ii) Similarly, the majority of candidates understood that compound **D** must be a ketone.
- (iii) Fewer were able to identify the alcohol as $CH_3CH(OH)CH_3$.
- (iv) Only a minority of candidates deduced that this alcohol must come from the fourth structure given above.
- (d) This question was unusual because it asked candidates to consider the structures they had drawn and it was clear that many candidates appeared to have little difficulty in identifying any chiral carbon atoms present in a molecule. The majority of candidates gave the correct answer that none of the esters given above contains a chiral carbon atom. Examiners gave credit to those candidates who had (wrongly) drawn a compound with a chiral carbon atom and correctly identified it.

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Paper 9701/04

A2 Structured Questions

In general, there were some excellent answers from candidates, but many poor ones. Although some of the questions were testing, there were certainly quite a few candidates who, as usual, lost marks by not reading the question thoroughly enough.

Question 1

- (a) In **part (i)** quite a few candidates did not include mass numbers. Many gave 1:1:1 rather than 1:2:1 for **part (ii)**, and some confused Br with Cl and wrote 9:6:1.
- (b) Well done on the whole. A surprising number thought an oxidising agent ($\text{Na}_2\text{Cr}_2\text{O}_7$) was needed to reduce $-\text{CHO}$ to $-\text{CH}_2\text{OH}$.
- (c) Few candidates scored in **part (i)**. The most common answer seemed to be 189. They did not bother to calculate the M_r , or even, possibly, look at the sentence above the table. Those who did calculate the M_r often quoted this figure (217.8) as the molecular ion. In **part (ii)** some did not identify isotopic compositions.

Question 2

- (a) Yellow was a common wrong response.
- (b) Candidates rarely scored full marks here. Most candidates failed to appreciate that all reactions, other than the slow step, were to be considered as equilibria.
- (c) and (d) These parts worked well.
- (e) The “grading” of the question worked well to differentiate.
- (f) No real problems here.

Question 3

- (a) (i) This “bookwork” question worked well, as always. The usual misunderstandings between atomic and ionic radius were apparent in some answers.
- (ii) A number of candidates did not include data, but many who did include data used E^\ominus values instead of r^+ values.
- (b) (ii) A lack of (aq) or $(\text{H}_2\text{O})_6$ was noted on quite a number of scripts.
- (iv) and (v) These parts were mostly answered well.
- (vi) Quite a few missed the pale blue precipitate, as usual, and there were also a few $[\text{Cu}(\text{NH}_3)_6]^{2+}$ ions to be seen.

Question 4

- (a) Generally well-answered.
- (b) (i) Generally well-answered.
- (ii) Several candidates missed out the catalyst, while others quoted a temperature that was too low.
- (iii) This was very poorly. Most candidates did not consider only the bonds broken and made, so many errors crept in.

Question 5

- (a) **G** was fine, but **H** was given variously as the alcohol $\text{ArCH}_2\text{CH}_2\text{OH}$ or ArCH_2OH , or the amino-nitrile.
- (b) Candidates produced some good answers.

Question 6

- (a) Pretty good, although some thought Fehling's or 2,4-DNPH would distinguish.
- (b) Quite a few used bromine (with or without light) and predicted that **L** would decolourise the reagent, (perhaps due to free radical substitution), rather than **M**.
- (c) Those who went down the ester route often thought that conc. H_2SO_4 was needed along with the alcohol or phenol.
- (d) Candidates made heavy weather of this part, and few scored any marks. Those who hydrolysed the amide with NaOH and then tested for an alkaline gas, did not appreciate the alkalinity of propyl amine. Only a few recognised the easy test with universal indicator solution.

Question 7

- (a), (b) and (c) These parts worked well, and were on the whole well-answered.
- (d) This also worked well, but was less highly scoring. A good discriminator.

Question 8

- (a) (i) Many did not seem to see this part of the question.
- (b) (ii) Candidates' curves for the non-competitive inhibitor rarely started at a steeper gradient than the competitive curve.
- (c) A good discriminator. The good candidates knew the $-\text{SH}$ group, and were also able to explain the loss of tertiary structure.

Question 9

- (a) (i) Most candidates could answer this. Unravelling of the double helix was the most common wrong answer.
- (ii) Quite a few suggested the PCR reaction, or something "along the way", before electrophoresis.
- (iii) Most used ninhydrin or similar, although the most able knew the use of radioactive phosphorus.
- (b) (i) and (ii) Candidates were not good at these parts, although they were potentially easy "bookwork" questions. Generally, candidates had not studied NMR in enough detail to appreciate its strong points.

- (c) **Part (i)** was well done, but in **part (ii)** most ignored the peak at δ 6.2, and although they explained the splitting well, did not piece it all together to give an ethyl group.

Question 10

- (a) (i) This question generally worked well, although some candidates were unable to relate the diagrams to potential bonding.

(ii) and (iii)

These did not work quite so well. Candidates who scored a mark or two seemed to do so fairly randomly.

(b) (i) and (ii)

These parts worked well.

- (iii) Many candidates did not consider the variable nature of side chains of proteins.

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Paper 9701/05

Planning, Analysis and Evaluation

General comments

Overall, the paper again proved to be quite challenging with some of the part questions only occasionally producing a correct response. Nevertheless, correct responses to all the questions were seen. Very high marks were extremely rare while some candidates failed to achieve any marks at all. Candidates often failed to appreciate the precision of answer required by some of the questions and there was evidence of candidate unfamiliarity with some of the concepts involved. An enhanced familiarity with experimental techniques would be of benefit to all candidates.

Comments on specific questions

Question 1

- (a) Most candidates were able to predict correctly that the solubility of the cerium(IV) sulphate would decrease with increasing acid concentration. However, the explanations were often too imprecise as were the graphs. Although the given graph axes were without numbers it was felt that candidates should start the line on the y-axis thereby indicating a particular value for the solubility and then draw either a curve or a straight-line with a negative slope that stopped short of the x-axis. Drawing a line to the x-axis, it was felt, would imply insolubility.
- (b) The majority of the candidates were able to access these marks.
- (c) Only a relatively small number of candidates scored all the four marks available in **Part 1**, the most common result being one or two marks. The outline method required for the first mark was generally well done, the main error being not recording either stirring or allowing time for saturation to occur. Coupled with this was an indication of the mass determinations required in order to calculate the solubility. These were usually correctly indicated and ideally included in the table in **(e)**. The control of the temperature was often incorrectly achieved, either by constant monitoring of the temperature or thermostating the whole laboratory. Only a small number of candidates were able to give a correct calculation method, perhaps overlooking the definition given earlier in the question. In **Part 2**, again, the most frequent occurrence was a mark of one or two. Although the requirement in this section was to detail how the various acid dilutions would be prepared quite a number of candidates chose to describe the complete experiment for a second time. A full range of dilutions was expected, covering a range up to 5 mol dm^{-3} with enough solution to allow the continued use of 60 cm^3 . In many cases, these two aspects were covered sometimes with the detail being in the table in **(e)**. However, the need to have accurate dilutions by using items of apparatus such as pipettes was not always appreciated by the candidates. Sometimes there was no apparatus mentioned while some candidates chose measuring cylinders.
- (d) The corrosive nature of the sulphuric acid was in most cases correctly identified.
- (e) Fully correct tables were only seen rather infrequently. Sometimes the concentrations of the acid were not given, but more frequently the necessary masses were not fully recorded. The masses to be recorded would be those indicated earlier if the **Part 1** plan had been correct. There was a tendency to record unnecessary data and in some cases, there were no units in the table.

Question 2

- (a) There was a very wide variety of data columns added to the table. The only two columns needed was one showing the cumulative mass of copper deposited and a second showing the increasing number of coulombs used. Any extra columns were ignored. Where the two correct columns were given the labelling was generally correct. One common error was to record the various mass changes for each 40 minutes. Use of such masses made it very difficult to assess the quality of the graph work and subsequent sections sometimes became impossible to answer. A second common error was to ignore the cathode masses and instead use the Faraday constant to calculate the masses of copper deposited. Because of this, the graph if correctly plotted gave a perfect straight-line passing through the origin. While this could access the 4 marks available in (b), subsequent marks based on the experimental results were not accessible. Other variations were the utilisation of the moles of copper (although if processed correctly this could lead to all sections being accessible) and the subtraction of 63.5 from the various cathode masses.
- (b) Many candidates plotted excellent graphs resulting in a straight-line passing through the origin with the result at 280 minutes being clearly anomalous and showing a mass greater than was appropriate. Where possible the graphing skills were assessed irrespective of which two variables were plotted. The graphs including the individual mass differences were difficult to assess on occasions.
- (c) Most candidates were able to identify an anomalous point on the graph and where this was on the correct graph, the correct suggestion of a 'wet' cathode was given.
- (d) This question demanded a precise answer and it proved difficult to access the mark. In order to produce a decreased percentage error the mass measured needs to be small and this second point proved the obstacle for most candidates.
- (e) This section was often left blank. Where appropriate construction lines were drawn, and the correct values recorded from the graph, the first mark was gained. The subsequent calculation often failed to take account of the fact that the copper ion has a double charge.
- (f) If a correct calculation had been carried out in (e) reference to a good agreement with the quoted value accessed one of the marks while the second was gained by reference to a straight-line either passing through the origin or with very few points not on the line. Candidates who did not appreciate the difference between a line and a straight-line often missed this second mark.
- (g) Again, this section was often left blank and only a very few candidates gave the correct response (the mass of the anode).
- (h) In nearly all cases this section was either left blank or had an incorrect answer.

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Paper 9701/31

Advanced Practical Skills 1

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data for each session/laboratory and the associated seating plans. 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 a corresponding set of Supervisor results. Regrettably a number of Centres continue to provide no Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence. Some other Centres do provide Supervisor data where multiple sessions have been held but there is insufficient data to place individual candidates within each session.

Question 1 involved a straight forward acid/base titration; **Question 2** a measuring exercise heating to constant mass and **Question 3**, test-tube reactions featuring simple observations and deductions.

Comments on specific questions

Question 1

As the acid (**FA 1**) was diluted and then used in the burette for the titration, each titre was scaled to find the volume of **FA 3** that would have been required to neutralise 25 cm³ of **FA 2** if 38.50 cm³ of **FA 1** had been diluted to 250 cm³. In many Centres the scaled titres were close to the Supervisor value, but in some a wider than expected spread of scaled titre values was seen.

- (a) (i) Most candidates recorded initial and final burette readings in each of the tables. A small number of candidates recorded 50.00 cm³ as the initial burette reading – presumably because they had filled the burette to the zero mark, with 50 cm³ of solution. These candidates were not awarded the first mark but the Examiners assumed the initial burette reading to be zero when calculating the volume diluted and in determining the “quality” (accuracy) marks.
- (ii) The majority of candidates appreciate that burette readings (other than rough or trial readings) should be recorded to the nearest 0.05 cm³. It was pleasing to see that very few candidates claimed to be able to read a burette to 0.01 cm³.
- (iii) Nearly all candidates gained the third mark for diluting a volume of **FA 1** between 38.00 cm³ and 39.00 cm³.
- (iv) Most candidates obtained two “accurate” titres within 0.1 cm³. Many candidates, however, having obtained their first two “accurate” titres within 0.1 cm³, wasted time by performing further titrations
- (v) and (vi) The Examiners selected and scaled the “best” average from the candidate’s titres and compared the scaled titre to that obtained by the Supervisor. In many Centres most of the candidates scored one or two marks, but some Centres were seen where the standard of titration was very poor, and the candidates’ scaled titres differed greatly from each other and from the Supervisor.
- (b) The derivation of the average for use in the calculation was generally well answered but a number of candidates failed to notice the instruction to “show clearly how you obtained this volume”. A mathematical expression for the average, or ticked titres in the table were acceptable as “showing clearly” how the average was derived. Some candidates did not gain this mark as they selected values with a spread greater than 0.20 cm³.

- (c) (i) Many candidates gained the mark for the first step in the calculation but a significant number calculated only the concentration of the sodium hydroxide in mol dm³ and omitted the volume of solution pipetted into the conical flask.
- (ii) Candidates familiar and competent with titration calculations had no difficulty in gaining this mark for correct expressions in step 2 and step 3 of the calculation.
Common errors seen in the 2nd step were to multiply by $\frac{1000}{\text{titre}}$, $\frac{1000}{25}$; or $\frac{250}{25}$.
A common error seen in the 3rd step was to multiply by $\frac{1000}{\text{volume diluted}}$.
- (iii) The majority of candidates gained the mark for showing working in steps 1 to 3 of the calculation.
- (iv) Many candidates failed to show appropriate significant figures in the final answers given in steps 1 to 3. Examiners were looking for 3 or 4 significant figures in each step. As an example, candidates who missed the volume pipetted in the first step and simply calculated $\frac{3.40}{40}$ gave the answer as 0.085 (the calculator display), an answer to only 2 significant figures.
- (v) The mark was awarded in this section to candidates who correctly evaluated **to three significant figures**, ^{38.68}/_{their answer to the previous step}. The requirement to calculate an answer to three significant figures was emboldened in the question paper but many candidates calculated values with greater or lesser precision. Some examples of “double rounding” were seen – e.g. a value of say 63.547 was first rounded to 63.55 and then to 63.6 rather than being rounded in one stage to 63.5. Some candidates gave a mass unit for the relative molecular mass.

Question 2

- (a) (i) Most candidates recorded the masses measured, but some failed to notice the instruction to also record the final mass of the residue and the mass of water driven off.
- (ii) Despite the final bullet point in the instructions – *Continue the heating, cooling and weighing until you are satisfied that all of the water of crystallisation has been driven from the crystals* – only 50% of candidates gave an indication of any reheating and reweighing.
- (iii) An even smaller proportion of candidates showed evidence of heating to constant mass – two weighings within 0.1 g being the criterion for constant mass used by the Examiners in this experiment. Where candidates had reheated and reweighed more than twice, it was apparent that tubes had not been heated strongly, as instructed.
- (iv) Headings and units were generally satisfactory but a number of candidates interchanged the mass of the residue and the mass of water driven off. Centres are reminded of the information, given in the syllabus, concerning acceptable forms of displaying units in tables. It was noted that many candidates referred to mass in one line of a table and weight in another line of the same table. No penalty was applied but consistency, mass or weight, is desirable.
- (v) Nearly all candidates recorded balance readings consistent to 1, 2 or 3 decimal places depending on the balance used.
- (vi) and (vii) The Examiners calculated for each candidate $\frac{\text{mass of water}}{\text{mass of residue}}$ and compared this to the theoretical value of 1.05 for magnesium sulphate.

Candidates who had heated the sample strongly, obtained values close to 1.05 and earned both of the “quality” (accuracy) marks. It was noted that a number of candidates who reheated and reweighed a number of times and reported constant mass after heating failed to gain either of these marks as their samples were clearly not fully dehydrated.

- (b) Most candidates were awarded this mark for calculating the % of water of crystallisation from their experimental results
- (c) The Examiners were surprised that many candidates left the two spaces in the table blank. Most candidates did make an attempt at matching the % calculated in (b) with a value for **x** from the table. A small number of candidates knew the formula of magnesium sulphate to be MgSO₄·7H₂O, it being a standard substance used in this experiment. There was some evidence of a few such candidates manipulating their results to give this outcome and often making mistakes in the process.

- (d) This was the first time that a question has been asked about reliability of experimental evidence and it was poorly answered. Many candidates assumed that repeating the experiment was to ensure all the water of crystallisation had been driven off - confusion with continued heating.

The Examiners were looking for consistent results from repeated experiments or the ability to eliminate anomalous results. The ability to take an average on its own was not accepted, but an average of consistent results would have been acceptable. The reduction of random error was just accepted as an answer but with hindsight Examiners would restrict acceptable answers to consistency of measurements or the selection and elimination of anomalous results

- (e) A question on percentage error that was set in a slightly different context to previous papers. It proved to be a difficult question, many candidates leaving the section blank.

Question 3

- (a) (i) A reference to density was needed and a statement as to which gas would be tested first. The Examiners had hoped to see simple calculations from the data given to establish the densities of the gases. As few candidates did any calculation, a reference to hydrogen being the lightest gas was accepted. Hydrogen formed in any reaction is lost very quickly from the reaction vessel and must be tested first. Carbon dioxide, having a much higher density than air, can be tested at leisure. The anticipated order for testing the gases was therefore hydrogen, followed by oxygen, followed by carbon dioxide. It is possible to perform all three tests, in sequence, in a number of seconds.
- (ii) The Examiners expected to see the gases tested in the order stated in (i). Many candidates correctly stated that hydrogen had to be tested first as it is the lightest gas, but then recorded the test for oxygen and/or carbon dioxide before the test for hydrogen.

Tests for the gases were often inadequately described, e.g. the pop test for hydrogen. Many candidates showed confusion between a burning/lighted splint and a glowing splint.

- (b) The sequence of tests and expected observations is shown in the table below for each of the gases.

test	gas present		
	hydrogen	oxygen	carbon dioxide
Place a burning splint into the gas	The gas burns with a "pop". (The lighted splint may be extinguished by the "explosion" as hydrogen is ignited.)	The lighted splint burns more brightly.	The lighted splint is extinguished.
Place a glowing splint into the gas	The glowing splint is extinguished.	The glowing splint is "rekindled" – often with a "pop" sound.	The glowing splint is extinguished.
Bubble the gas through limewater or suspend a drop of limewater in the gas, e.g. on a glass rod	Limewater is unchanged.	Limewater is unchanged.	Limewater turns milky/cloudy/chalky or a white precipitate is formed.

- (c) Candidates were instructed to add a **very small** amount of **FA 5** to potassium iodide solution. They were expected to see a yellow solution as the **FA 5** oxidised iodide ions to iodine – confirmed by a blue/black/purple solution when starch was added.

A very large number of candidates recorded a black precipitate on adding **FA 5** and also after adding the starch – too much of the solid had been added and no observations were possible in the solution.

When a black solid is added to a solution and a black solid settles in the tube, candidates should realise that the formation of a black precipitate is not a justifiable observation as a precipitate is **formed** from a solution.

Answers to this section were disappointing. Sufficient evidence was given in the rubric of the question to indicate that **FA 5** was a catalyst. Many candidates who correctly stated catalyst here were unable to make the connection to a compound of a transition metal. In test **(b)** the **FA 5** was acting as an oxidant – this deduction depended on the observations obtained in **(b)**. For those who did not state that **FA 5** was acting as a catalyst in **(a)** but did state from correct observations that **FA 5** acted as an oxidant in **(b)** there was a second opportunity to gain the mark for a transition element.

- (d)** The Examiners were expecting to see a green precipitate insoluble in an excess of each reagent for **FA 6**. Dark green, dirty green or muddy green were accepted as colours of the precipitate, but not grey-green.

A grey-green precipitate soluble in excess sodium hydroxide was recorded by many candidates – with the consequential and incorrect deduction of chromium(III) ions.

The Examiners also expected to see a brown/red-brown/orange-brown/rust (but not red) precipitate insoluble in an excess of each reagent for the mixture of **FA 6** and **FA 7**.

Marks were awarded for recording **(i)** an initial precipitate in each test; **(ii)** the solubility of any initial precipitate with an excess of the reagent; **(iii)** the correct colours of precipitates for **FA 6**, **(iv)** the correct colours of precipitates with the mixture of **FA 6** and **FA 7**; **(v)** correct conclusions from correct observations.

The Examiners are at a loss to explain why in **(v)** many candidates with perfect observations and a correct deduction of Fe^{2+} ions in **FA 6** and Fe^{3+} ions in the mixture of **FA 6** and **FA 7** stated that **FA 7** was acting as a reductant/reducing agent.

- (e)** This section was generally well answered. Most candidates correctly added barium chloride followed by hydrochloric or nitric acid. A small number of candidates added sulphuric acid after the barium chloride – barium sulphate precipitate, insoluble in acid, would replace barium sulphite precipitate, soluble in acid, so the test would be invalid. For that reason the Examiners did not accept the addition of an unspecified acid as this could also have been sulphuric acid.

A number of candidates stated that they would test **FA 6** with an acid and look for effervescence from a sulphite. Sulphites do produce gas (bubbles) when reacting with an acid but it could never be described as effervescence unless a hot concentrated solution of the sulphite was used. Candidates who added the acid and tested for sulphur dioxide with a suitable oxidant (e.g. acidified dichromate) were rewarded.

CHEMISTRY

Paper 9701/32

Advanced Practical Skills 2

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data for each session/laboratory and the associated seating plans. 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 a corresponding set of Supervisor results. Regrettably a number of Centres continue to provide no Supervisor information. Examiners take steps to obtain the missing data through CIE but it is often unobtainable and candidates may be disadvantaged as a consequence. Some other Centres do provide Supervisor data where multiple sessions have been held but there is insufficient data to place individual candidates within each session.

Question 1 involved an iodine/thiosulphate titration; **Question 2** a quantitative exercise involving mass changes during a reaction and **Question 3**, test-tube reactions featuring simple observations and deductions.

Comments on specific questions

Question 1

As the potassium manganate(VII) (**FB 2**) was diluted and then pipetted into the conical flask for the titration, each titre was scaled to find the volume of **FB 1** that would have been required to neutralise 25 cm³ of **FB 3**, the diluted solution, if 41.50 cm³ of **FB 2** had been diluted to 250 cm³. In many Centres the scaled titres were close to the Supervisor value but in some a wider than expected spread of scaled titre values were seen.

- (a) (i) Most candidates recorded initial and final burette readings in each of the tables. A small number of candidates recorded 50.00 cm³ as the initial burette reading – presumably because they had filled the burette to the zero mark, with 50 cm³ of solution. These candidates were not awarded the first mark but the Examiners assumed the initial burette reading to be zero when calculating the volume diluted and in determining the “quality” (accuracy) marks.
- (ii) The majority of candidates appreciate that burette readings (other than rough or trial readings) should be recorded to the nearest 0.05 cm³. It was pleasing to see that very few candidates claimed to be able to read a burette to 0.01 cm³.
- (iii) Nearly all candidates gained the third mark for diluting a volume of **FB 2** between 41.00 cm³ and 42.00 cm³.
- (iv) Most candidates obtained two “accurate” titres within 0.1 cm³. Many candidates however, having obtained their first two “accurate” titres within 0.1 cm³ wasted time by performing further titrations
- (v) and (vi) The Examiners selected and scaled the “best” average from the candidate’s titres and compared the scaled titre to that obtained by the Supervisor. In many Centres most of the candidates scored one or two marks but some Centres were seen where the standard of titration was very poor and the candidates’ scaled titres differed greatly from each other and from the Supervisor.
- (b) When calculating an average titre from experimental results, candidates should always select titres within a spread of 0.20 cm³.

- (c) (i) Most candidates gained the mark for the first step in the calculation.
- (ii) The second mark was given for using the correct mole ratios in steps 3 and 4 of the calculation. Many candidates failed to apply the correct ratio of $2.5 \text{ mol I}_2 \equiv 1 \text{ mol MnO}_4^-$ in step 3, but the majority applied the correct ratio of $1 \text{ mol I}_2 \equiv 2 \text{ mol S}_2\text{O}_3^{2-}$ in step 4.
- (iii) The majority of candidates gained the mark for showing working in at least three of the first four steps of the calculation. Balancing electrons in the half-equations was accepted as working.
- (iv) Many candidates failed to show appropriate significant figures in the final answers given in steps 1 to 4. Examiners were looking for 3 or 4 significant figures in each step. As an example; candidates who missed the volume diluted in the first step and simply calculated $\frac{28.44}{158}$ gave the answer as 0.18 (the calculator display), an answer to only 2 significant figures.
- (v) The mark was awarded in this section to candidates who correctly evaluated to **three significant figures**, their answer to step 4 $\times \frac{1000}{\text{titre}}$. The requirement to calculate an answer to three significant figures was emboldened in the question paper but many candidates calculated values with greater or lesser precision. Common errors seen in this section involved the use of the volume diluted rather than the titre or the omission of 1000 from the expression evaluated.

Question 2

- (a) (i) Most candidates recorded the masses measured but some failed to notice the instruction to also record the mass of the carbonate added and the mass of carbon dioxide given off.
- (ii) The Examiners were looking for a **single table** incorporating all balance readings or the balance readings for the flask + the mass of carbonate added for both **FB 6** and **FB 7**.
A single table has no repetition of headings:

	FB 6	FB 7
mass of flask + FB 8 before experiment / g		
mass of tube + carbonate before experiment / g		
mass of tube + residual carbonate / g		
mass of flask + contents after experiment / g		
mass of carbonate added / g		
mass of carbon dioxide given off / g		

Many candidates produced two tables – joined horizontally or vertically – one for each of **FB 6** and **FB 7**. By repeating all of the headings candidates doubled the possibility of errors in the headings themselves or in the inclusion of appropriate units.

- (iii) Headings and units were generally satisfactory. Centres are reminded of the information, given in the syllabus, concerning acceptable forms of displaying units in tables. It was noted that many candidates referred to mass in one line of a table and weight in another line of the same table. No penalty was applied but consistency, mass or weight, is desirable.
- (v) Nearly all candidates recorded balance readings consistent to 1, 2 or 3 decimal places depending on the balance used.
- (b) The Examiners checked and corrected where necessary the calculations in this section. The masses of **FB 6** and **FB 7** yielding 1.0 g of carbon dioxide were compared and “quality” (accuracy) marks awarded for the consistency of results for the two samples. Candidates who worked carefully produced very consistent results. A few candidates only used one of **FB 6** and **FB 7** in this experiment.
The Examiners were surprised by the number of candidates who were unable to use the given formula to correctly calculate the mass of carbon dioxide given off in the experiments.

- (c) Many candidates left this section blank. Candidates had calculated the mass of carbonate yielding 1 gram of carbon dioxide in (b) and were given the equation showing 1 mol carbonate \equiv 1 mol carbon dioxide in this section. The Examiners had anticipated that candidates would simply multiply each of the masses of carbonate calculated in (b) by 44. These simple calculations were seldom seen. Many incorrect and complex calculations involved the volume and concentration of the acid used.
- (d) Many candidates left this section blank. Candidates who scored the mark in this section referred to the acid spray during the reaction which they saw as a problem despite the instruction to add the solid slowly, or to the solid that stuck around the neck or on the sides of the flask. Candidates struggling for an answer showed a lack of understanding of the principles of the experiment referring to the loss of carbon dioxide during the experiment or to the solid remaining in the weighed tube. Some candidates considered the problem to be with the equipment used - incorrect mass measurement or the use of a measuring cylinder.
- (e) Many candidates also left this section blank. The most common correct answer was to warm the solution to eliminate dissolved carbon dioxide. Some candidates knew about saturating the solution with carbon dioxide before the experiment. A small number added carbonate to the acid before the experiment but did not explain the purpose of this addition.
- (f) The Examiners were very disappointed by the answers seen in this section. The first mark was simply obtained by careful observation and recording of the observations. It was not uncommon for candidates to record BaCO_3 and X_2CO_3 effervescing when added to water. Other candidates failed to record the evolution of any gas when the carbonates were added to the acid. Appropriate observations for three of the four boxes were required for the first mark. There had to be reference to evolution of gas in one of the "acid" reactions.
The Examiners expected to see the following from careful observation:

	BaCO_3	X_2CO_3
water	The white solid is insoluble and settles as a white powder in the bottom of the tube	The white powder dissolves and forms a colourless solution
FB 3 dilute sulphuric acid	A slow reaction producing some gas bubbles is seen initially but reaction soon stops and a white solid remains in the tube	Rapid effervescence and the solid dissolves to form a colourless solution

For the second mark the Examiners were looking for reference to the insolubility of the barium sulphate formed. Many candidates did not complete this part of the question.

Question 3

- (a) This section was answered well by the majority of candidates although a number of off-white precipitates insoluble in an excess of sodium hydroxide were reported. The majority of candidates reported on the solubility/insolubility of precipitates when an excess of the reagent was added.
- (b) Many candidates ignored the rubric in this section and gave only one possible cation for **FB 9**. A smaller number of candidates also gave only one cation for each of **FB 10** and **FB 11**.
- (c) This section proved to be the most difficult part of **Question 3**. The less complete the answers in (b) the more difficult this section became. Where candidates had correctly identified Ba^{2+} , NH_4^+ (and/or Ca^{2+}) as the possible cations in **FB 9** and Al^{3+} and Pb^{2+} as the possible cations in **FB 10** and **FB 11** they were expected to select appropriate reagents and perform confirmatory tests on the solutions. Candidates who had not given at least two ions for each of the solutions in (b) therefore found this section confusing.
Many candidates who had suggested NH_4^+ for **FB 9** referred to heating the solution but did not specify the solution they were heating. Others described red litmus turning blue but did not indicate that they were testing a gas. It was necessary to show that **FB 9** warmed with **aqueous sodium hydroxide** yielded a **gas**, which turned red litmus blue (or other test for ammonia gas).
Other candidates added aqueous potassium dichromate to test for Ba^{2+} and reported an orange precipitate, which should not have been seen, as no barium ions were present.

A small number of candidates having suggested Ba^{2+} and Ca^{2+} in (b) proceeded to test for and show the presence of NH_4^+ .

In testing **FB 10** and **FB 11** it was necessary to perform the tests on each of the solutions. A number of reagents were available to distinguish between Al^{3+} and Pb^{2+} . Hydrochloric acid was a suitable reagent but barium chloride was not as the presence of any sulphate ion would lead to erroneous results as happened with **FB 10**.

- (d) This was a straightforward section in which each solution needed to be tested with barium chloride and with silver nitrate. A large number of candidates misunderstood the rubric and assumed that one solution contained a halide, the other a sulphate. As a consequence they did not test each of the solutions with each of the reagents. **FB 9** did contain a halide and **FB 10** a sulphate but from the wording of the question there was the possibility of two halides or two sulphates. Many candidates failed to test the solubility of the silver halide precipitate (**FB 9**) in aqueous ammonia. Identification of the bromide ion was however allowed from an off-white or cream precipitate with silver nitrate alone or from a white precipitate partially soluble or insoluble in aqueous ammonia. A conclusion of iodide was allowed from a yellow precipitate with silver nitrate although this would not have scored the observation mark.