CHEMISTRY

Paper 9701/01
Multiple Choice

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

General comments

For this paper, the mean score was 22.9 (57.3%), slightly below the targeted value, and the standard deviation of the scores was 7.19 (18.0%), indicating that the paper discriminated very satisfactorily among candidates.

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

Comments on Individual Questions

Only two questions had facilities above the design limit. **Question 1** was a traditional 'easy starter' on relative atomic mass, and **Question 4** on the effect of an electric field on electrons, neutrons and protons. These clearly represent areas of the syllabus that are well understood.

Of other questions, all but three performed satisfactorily.

Two questions did not discriminate well within the ability range of candidates. In **Question 17** some of the more able candidates chose the distractor **D** rather than the key **C**. The question had asked candidates to identify the gaseous products when methyl mercaptan, CH_3SH, is burned in an excess of air. In addition to CO_2 and H_2O the key had given SO_2 as the sulphur-containing product, but the distractor **D** had given SO_3. Candidates should have known from the chemistry of the Contact process that oxidation to the level of SO_3 requires a catalyst.

In similar fashion in **Question 37** more candidates chose the distractor **C** rather than the key **A**. Surprisingly 48% of candidates thought that the endothermic reaction between gaseous nitrogen and oxygen would not be assisted by a considerable rise in temperature, as occurs in a hot car engine.

One other question deserves comment. In the context of cleaning dirty cooking pans, **Question 40** asked what possible cleaning agents would react with the ester groups in fats and greases. The only correct response was vinegar, containing aqueous ethanoic acid, correctly given by 25% of candidates, but 35% of candidates also included alcohol (ethanol) which requires an acid catalyst before reacting with an ester. It may be that there was confusion in that alcohol would act as a solvent and thus assist in the cleaning process, but the question did specifically limit the answer to those substances which **reacted** with the ester group.

CHEMISTRY

General comments

The paper tested candidates' knowledge and understanding of the required subject matter, and the majority of candidates made good attempts to complete all of the questions. Chemistry is an experimental science and a number of questions on this paper asked candidates to describe what they would observe when particular reactions are carried out. While there were many good answers to these questions, there were also many candidates who failed to describe the obvious things that would be seen, such as 'a brown gas would be evolved'. A number of candidates who clearly knew what was occurring in a particular reaction gave information that could not be observed <u>directly</u>, such as 'hydrogen is evolved which gives a pop test'.

There were many good answers to this paper and most candidates were able to demonstrate some positive achievement. Candidates' knowledge of organic chemistry continues to improve in general, but a large number of candidates struggled with one or both calculations, often because they did not use a logical method of answering the questions.

As in previous years, a number of candidates clearly had not prepared thoroughly for the examination by learning important factual chemistry, while a significant number of candidates gave some answers that were illegible or were muddled, with the result that examiners were unable to give them credit.
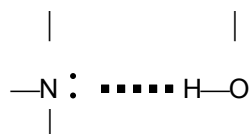
Comments on specific questions

Question 1

This question tested candidates' understanding of molecular structures and inter-molecular forces as applied to two compounds with similar molecular formulae. While there were many good answers overall, a large number of candidates gave very poor answers to part **(c)**.

(a) The majority of candidates knew that the H-C-H bond angle in ethene is approximately 120°. However, fewer candidates were able to give a correct 'dot-and-cross' diagram for hydrazine. The most common error was to fail to realise that each nitrogen atom in the hydrazine molecule, like the one in the ammonia molecule, has three covalent bonds. This means that each nitrogen atom has a lone pair of electrons. This results in three bonding pairs and one non-bonding pair of electrons in the hydrazine molecule, giving a H-N-H bond angle of about 107°.

(b) There were many good answers to this part with good descriptions of hydrogen bonding and van der Waals' forces and their relative strengths.

(c) This was very poorly done in the majority of answers. Examiners expected candidates to deduce that the hydrazine molecule, like that of ethanol, has dipoles and that with >NH and -OH groups present, hydrogen bonding will occur in the solution of the two compounds. Candidates should have shown correct dipoles on O—H and N—H bonds and a clearly labelled hydrogen bond between the O atom of ethanol and an H atom of hydrazine or between an N atom of hydrazine and the H atom of the –OH group in ethanol.

Many candidates used water instead of ethanol, or only drew one molecule, hydrazine or ethanol, so could not draw any hydrogen bonds between the two correct molecules.

Those candidates who clearly understood where the hydrogen bonds would be between the hydrazine and ethanol molecules were often penalised because they failed to show clearly the position of the lone pair of electrons in the hydrogen bond. Good answers would be either of the following.

$$—N \overset{\displaystyle |}{\underset{\displaystyle |}{:}} \bullet\bullet\bullet\bullet\bullet H—O$$

or

$$—O \overset{\displaystyle |}{:} \bullet\bullet\bullet\bullet\bullet \overset{\displaystyle |}{H}—N—$$

(d)(i) This was generally very well answered. Those candidates who were penalised usually failed to show the C=C bond clearly in their structural formula of ethene.

(ii) Most candidates knew this to be an electrophilic addition. Examiners did not accept 'addition' as a sufficiently correct answer.

(iii) This too was usually well answered with most candidates appreciating that chloroethane is a saturated molecule that will not react with HC*l*.

(e) Many candidates struggled with this final part of **Question 1**. Unlike ethene, the hydrazine molecule contains two lone pairs of electrons and each nitrogen atom can behave as a base and one or two molecules of HC*l* can react with one molecule of hydrazine.

Question 2

This question tested candidates' understanding of K_c and knowledge of the different reactions of primary, secondary and tertiary alcohols. While the majority of candidates knew most of the organic reactions concerned, relatively few were able to carry out the calculation correctly.

(a) The majority of candidates were able to answer this correctly. The most common error was to fail to state clearly that the <u>rates</u> of the forward and reverse reactions will be the same at equilibrium.

(b) Most candidates gave a correct answer to this part. Those who represented concentrations as (CH_3CO_2H) rather than $[CH_3CO_2H]$ were penalised as were those who omitted $[H_2O]$ from their expression.

(c) Many candidates really struggled with this calculation. Examiners felt that the main reason for their difficulty was that they were unable to deduce the equilibrium concentrations of each component present in the equilibrium mixture. One straightforward method of doing this is shown below.

	CH_3CO_2H +	C_2H_5OH ⇌	$CH_3CO_2C_2H_5$ +	H_2O
initial moles	0.5	0.5	0.1	0.1
equil. moles	(0.5-x)	(0.5-x)	(0.1+x)	(0.1+x)
equil. concn./mol/dm^{-3}	$\dfrac{(0.5-x)}{V}$	$\dfrac{(0.5-x)}{V}$	$\dfrac{(0.1+x)}{V}$	$\dfrac{(0.1+x)}{V}$

These equilibrium concentrations can then be put into the expression for K_c. When carrying out this process, V disappears.

$$K_c = \frac{[CH_3CO_2C_2H_5][H_2O]}{[CH_3CO_2H][C_2H_5OH]} = \frac{(0.1+x)^2}{(0.5-x)^2} = 4$$

To solve this equation, it is not necessary to use the expression for the solution of a quadratic equation. Indeed the syllabus, in **Section 7(f)**, states that this method will not be required. Taking square roots of the above equation gives the following.

$$\frac{(0.1 + x)}{(0.5 - x)} = 2$$

whence x = 0.3

thus $n(CH_3CO_2H) = n(C_2H_5OH) = 0.2$ mol and
        $n(CH_3CO_2C_2H_5) = n(H_2O) = 0.4$ mol

(d)   Many candidates correctly identified the products of the reactions concerned. One common error was to fail to give a structural formula, i.e. one clearly showing a C=C bond, for the product of the dehydration of $(CH_3)_3COH$. Another was to give an aldehyde rather than a carboxylic acid for the oxidation of $CH_3CH_2CH_2CH_2OH$. In the latter case, heating the reagents under reflux will ensure complete oxidation occurs.

Question 3

This question tested candidates' knowledge and understanding of some of the chemistry of Group II elements. There were many good answers to this question but a significant number of candidates gave answers to parts **(c)** and **(d)** that lacked good descriptions of what would be seen.

(a)   Most candidates were able to complete the table satisfactorily. Candidates are advised to use the *Data Booklet* to check their answers to questions of this type.

(b)   There were many very good answers to this part but some candidates were penalised by not giving clear and unambiguous explanations of the trends they were discussing. A good answer to parts **(i)** and **(ii)** will explain that atomic radii increase down Group II because more shells of electrons are present down the Group, and that when the <u>outermost shell</u> of electrons has been removed from the strontium atom the resulting strontium cation is smaller.

Examiners expected answers to part **(iii)** to explain that down the Group the outermost electrons are further away from the nucleus and there is <u>increased shielding</u> by inner electron shells.

(c)   While there were many reasonable answers to this part, few candidates explained clearly and accurately what would be seen. If a piece of magnesium ribbon is placed in water and left for some time, a layer of bubbles will be seen on its surface. The gas produced is colourless. In the case of calcium, the metal reacts much more readily and will dissolve, with the solution becoming 'milky' in appearance and a colourless gas being produced. Most candidates were able to write correct equations but some were penalised because their equations were unbalanced.

(d)   When solid strontium nitrate is heated, a brown gas, which is nitrogen dioxide, is produced. Many, but not all, candidates knew this. Fewer were able to write the correct equation for the reaction.

$$2Sr(NO_3)_2 \rightarrow 2SrO + 4NO_2 + O_2$$

Question 4

This question tested candidates' knowledge of simple organic reactions and understanding of structural isomerism and stereoisomerism. As in previous questions on this paper, a significant number of candidates gave poor descriptive answers in parts **(a)** and **(d)**. While the majority of candidates answered part **(b)** correctly, large numbers struggled to draw the correct isomers in parts **(c)** and **(e)**.

(a) Examiners expected candidates to make simple statements in each case, such the following.

(i) observation a white precipitate would be formed
product responsible silver chloride

(ii) observation white fumes would be formed
product responsible hydrogen chloride

(iii) observation a colourless gas would be formed
product responsible hydrogen

(b) The majority of candidates were able to give fully correct answers to this calculation. Those candidates who were unable to do so clearly did not know how to use the values of relative atomic mass, which are to be found in the *Data Booklet*, as shown below.

$$C : H : O = \frac{40}{12} : \frac{6.7}{1} : \frac{53.3}{16}$$

$$= 3.33 : 6.7 : 3.33$$

$$= 1 : 2 : 1$$

Hence the empirical formula is CH_2O.
Examiners expected candidates to show their working.

(c) The question required candidates to produce three <u>displayed formulae</u> for the molecular formula $C_2H_4O_2$, other than the two structures already given in the question. While many candidates were able to give at least two correct answers, there was a significant number who repeated the structures already given in the question, or who gave the same structure twice.

When the question asks for <u>displayed formulae</u>, it means that candidates should show both the relative placing of the atoms in the molecule and the number of bonds between them. Details are given in **Section 10.1** of the syllabus. Examiners penalised those candidates who gave an incorrect arrangement of atoms such as the structure below.
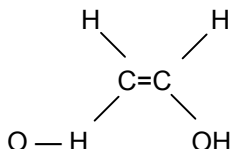
There are only three structural isomers that meet the requirements of the question and these are shown below.

X	Y	Z
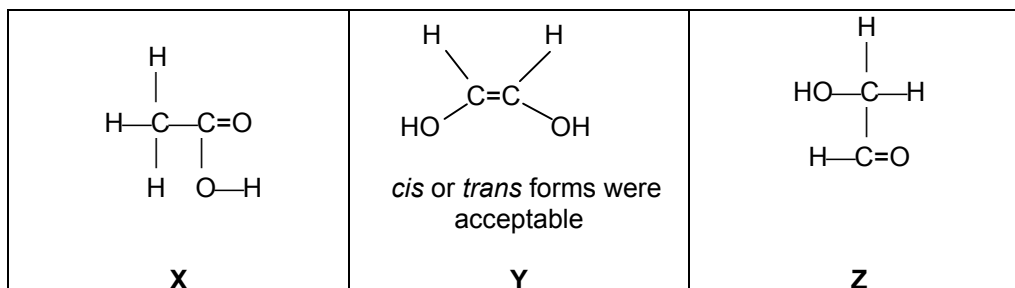
(d)(i) This was quite well answered with many candidates correctly choosing their carboxylic acid (**X** above) and giving a correct observation.

(ii) In this part, while many candidates correctly identified their aldehyde (**Z** above), they confused Tollens' reagent with Fehling's solution and gave the observation for the latter.

(e)   Many, but not all, of those candidates who had deduced structure **Y** were able to draw the *cis* and *trans* forms of it correctly. There were, however, some candidates who clearly did not understand the difference between structural isomers and stereoisomers and a small number who thought that stereoisomerism only concerns compounds containing chiral carbon atoms. Some candidates were penalised because, having drawn two correct structures, they failed to label them *cis* and *trans* as the question required.

CHEMISTRY

General comments

The Examiners thank Supervisors at Centres who supplied, as requested, experimental data for each session/laboratory and 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 information to determine which candidates were in which session.

Every mark on the Paper was awarded but fewer candidates obtained very high marks on this new style of practical paper when compared to the old style paper 3. The changes were particularly noticeable in **Question 3** – the observation and deduction exercise. The Examiners anticipate that Centres will learn from this examination and report and that high marks will become more common in subsequent sessions.

Comments on specific questions

Question 1

As the hydrochloric acid (**FA 2**) 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 cm^3 of **FA 1** if 32.00 cm^3 of **FA 2** had been diluted to 250 cm^3. Examiners generally found a wider spread of scaled titre values than expected.

(a)   Candidates were asked to record burette readings and the volume added in each of the tables. The tabulation of burette readings and titres in the second, titration table, was generally good with initial and final burette readings recorded, all accurate burette readings shown to the nearest 0.05 cm^3, the volume of **FA 3** run from the burette in each titration shown and a sufficient number of titrations performed. Comparatively few "rough" titrations were recorded. The Examiners accepted rough + two other titrations or three titrations overall as a sufficient number. Two titres only were accepted as sufficient providing the two volumes added from the burette were within 0.10 cm^3.

Unfortunately many candidates did not gain the first or second mark in **(a)** as they gave no burette readings in the dilution table – merely giving the volume diluted.

Further marks were awarded for recording <u>all burette readings</u> in titrations, other than a rough titration, to the nearest 0.05 cm^3, for performing sufficient titrations and for obtaining two titres within 0.10 cm^3. Most candidates scored well in this section.

Two accuracy marks were available from a comparison of the Examiner derived "best" scaled average titre and the scaled titre for the Supervisor results. Within most Centres the range of 0, 1, or 2 marks were awarded.

(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".

(c) Unlike the old paper 3 there was not a mark for each step of the calculation. Two marks only were awarded for chemical arithmetic in the first four steps of the calculation. Each chemical error led to the loss of one of these two calculation marks.

One further mark in the section was awarded for showing working in each step and one mark for working to sufficient significant figures (3 or 4 sf in the final answer to each step). The final mark was for expressing, correct to 3 significant figures, the answer to step 5 as a % of 4.50 g. Candidates who through errors in the early steps of the calculation obtained an answer to step 4 that was greater than 4.50 often inverted the final expression.

Most candidates showed working in all of the steps attempted. Many candidates failed to work to 3 or 4 significant figures – a few gave too many significant figures but the majority falling into this category showed only 2 significant figures.

As the diluted acid was placed in the burette, the correct answer to step 2 was to multiply the answer to step 1 by $^{titre}/_{250}$. Many candidates multiplied by $^{titre}/_{1000}$.

There were two chemical processes in step 3. Most candidates correctly calculated the moles of sodium carbonate in 25.0 cm^3 of **FA 1** but omitted to multiply by $^{1000}/_{25}$. Most candidates correctly multiplied by 106 in step 4.

(d) Each candidate should have been provided with a 25 cm^3 measuring cylinder. A surprisingly large majority of candidates were unable to read the smallest division on a cylinder of this size. The Examiners expected the smallest division to be 0.5 cm^3. Examiners are aware that some cylinders exist with different graduations. They were careful to check the responses of candidates within a Centre where unexpected values were recorded to see if there was any consistency between candidates indicating a particular cylinder had been issued to candidates. Such consistency was seldom seen.

Many candidates have not yet realised that the estimated error is taken to be ½ of the smallest scale division, i.e. 0.25 cm^3. The % error in the measuring cylinder was marked consequentially to the estimated error given in the first part of **(d)**. Many candidates gained the mark for calculating this value and the % error for the pipette (0.24%). A small number of candidates calculated 0.24% for the pipette and then gave 0.2% as the final answer, which was not accepted.

(e) Many candidates misunderstood the intention of this section. Two titrations should have been performed using the measuring cylinder rather than the pipette to deliver 25.0 cm^3 of **FA 1**. Most candidates performed only one titration and it appeared from the subsequent explanation that some used the measuring cylinder in place of the burette not pipette.

The mark scheme was amended to take account of this misunderstanding and the mark was awarded if candidates: compared the consistency of two titres using the measuring cylinder; compared any titre using the measuring cylinder with the titres obtained in **(a)**; compared the <u>% error</u> of the measuring cylinder and pipette to suggest that titres would not be consistent.

(f) Very few candidates appreciated that warming the solution during the titration would drive off dissolved carbon dioxide. Many candidates suggesting adding acid, alkali or limewater to the titration mixture.

Question 2

(a) Candidates were required to record their results in an appropriate format. Marks were awarded for recording in a table all of the weighings and temperature measurements, the mass of **FA 4** added and the change in temperature; putting data for each of the experiments in a single table; correctly labelling rows/columns including the appropriate unit and for recording all weighings consistently to at least 1 decimal place and all temperature measurements to 1 decimal place.

Many candidates omitted one or both of the following:
the mass of tube + residual mass of **FA 4**;
units – where units were not included in column headings, every individual reading required the appropriate unit;

Temperatures were often recorded to whole numbers only or with 2 decimal places.
Weighings were generally recorded consistently to 1, 2 or 3 decimal places depending on the balance provided by the Centre.
For a single table to be rewarded, no "label" should be repeated. The following is a single table.

	experiment 1	experiment 2
mass of empty tube /g		
mass of tube + **FA 4** /g		
mass of tube + residual **FA 4** /g		
mass of **FA 4** added /g		
initial temperature /°C		
final temperature /°C		
change in temperature, ΔT /°C		

The following however is not a single table:

	experiment 1			experiment 2
mass of empty tube /g		mass of empty tube /g		
mass of tube + **FA 4** /g		mass of tube + **FA 4** /g		
mass of tube + residual **FA 4** /g		mass of tube + residual **FA 4** /g		
mass of **FA 4** added /g		mass of **FA 4** added /g		
initial temperature /°C		initial temperature /°C		
final temperature /°C		final temperature /°C		
change in temperature, ΔT /°C		change in temperature, ΔT /°C		

(b) The Examiners corrected any errors in subtraction in the results table and calculated ΔT/m for each experiment. One accuracy mark was given for the consistency of the candidate's own results and one accuracy mark for the consistency of the candidate with the Supervisor. A full range of 0, 1 and 2 marks was seen.

(c) The Examiners expected candidates to make a judgement on the need for further repeats based on the consistency of the results obtained from the two experiments. Very few candidates referred to the results they had obtained but made generalised statements about greater accuracy with more repeats.

(d) Most candidates were able to calculate the % purity using the mean value for ΔT/m and the expression given. A small number of candidates introduced an additional factor of 100 into the denominator.

Question 3

(a) Many candidates failed to observe, or record, any evolution of gas when **FA 6** reacted with nitric acid. Even where effervescence was recorded there was seldom any test on the gas to show the presence of carbon dioxide – despite the instruction, in bold, to test any gas and describe the test in the observations. Most candidates also failed to record a colourless solution when **FA 6** dissolved in the acid. Many white solutions were recorded. No white solutions exist – candidates either observed the bubbles of gas in the solution or a suspension of the white solid. One mark awarded from the four available was very common in this section.

(b) Most candidates were able to put their observations into a table and generally into a single table although the second mark was lost where the reagent was repeated in row/column headings against **FA 6** and **FA 7**. Most candidates did record all observations up to and including the addition of an excess of the reagent.

Most candidates correctly reported a white precipitate soluble in excess for **FA 6** with sodium hydroxide and ammonia solutions.

Two marks were available for careful observation during the addition of sodium hydroxide and aqueous ammonia to **FA 7**. Few candidates obtained the first mark, which was for a paler blue precipitate on first addition of aqueous ammonia when compared to the precipitate with sodium hydroxide solution. Many candidates scored the second mark for the blue precipitate with ammonia dissolving in excess reagent to form a dark blue solution. Dissolving of the precipitate and not just the dark blue solution was necessary for this mark and was missed by many candidates.

(c) Most candidates were able to identify zinc as the cation and explain the supporting evidence. Where the white precipitate formed had been insoluble in an excess of one or both reagents, the identity of the cation was marked consequentially.

The identification of copper(II) or Cu^{2+} was allowed from a blue precipitate with both sodium hydroxide and with ammonia or from the dark blue solution with (excess) ammonia.

The conclusion that the anion in **FA 6** was only allowed where carbon dioxide had been tested and identified or from an observation of effervescence when **FA 6** reacted with the acid. Many candidates missed this mark because of poor observations in **(a)**.

(d) Candidates were asked to select appropriate <u>reagents</u>. They should realise that reagents are chemicals such as silver nitrate or lead nitrate and not single ions. The Examiners were hoping to see silver nitrate followed by aqueous ammonia to dissolve the silver chloride precipitate and lead nitrate as the other reagent. Aqueous silver ions, aqueous lead(II) ions or solutions containing these ions were accepted as reagents in less than perfect answers. Some candidates did not earn one of the marks in this section by giving only the formula of lead nitrate and writing it incorrectly as $PbNO_3$. It is safer to name the reagent unless absolutely certain the formula is correct.

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 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 information to determine which candidates were in which session.

Every mark on the Paper was awarded but fewer candidates obtained very high marks on this new style of practical paper when compared to the old style paper 3. The changes were particularly noticeable in **Question 3** – the observation and deduction exercise. The Examiners anticipate that Centres will learn from this examination and report and that high marks will become more common in subsequent sessions.

Comments on specific questions

Question 1

As differing volumes of the ammonium iron(II) sulphate (**FB 1**) were diluted and then pipetted into the conical flask for the titration, each titre was scaled to find the volume of **FB 2** that would have been required to neutralise 25 cm^3 of **FB 3** if 38.00 cm^3 of **FB 1** had been diluted to 250 cm^3. Examiners generally found a wider spread of scaled titre values than expected.

(a) Candidates were asked to record burette readings and the volume added in each of the tables. The tabulation of burette readings and titres in the second, titration table, was generally good with initial and final burette readings recorded, all accurate burette readings shown to the nearest 0.05 cm^3, the volume of **FB 2** run from the burette in each titration shown and a sufficient number of titrations performed. Comparatively few "rough" titrations were recorded. The Examiners accepted rough + two other titrations or three titrations overall as a sufficient number. Two titres only were accepted as sufficient providing the two volumes added from the burette were within 0.10 cm^3.

Unfortunately many candidates did not gain the first or second mark in **(a)** as they gave no burette readings in the dilution table – merely giving the volume diluted.

Further marks were awarded for recording <u>all burette readings</u> in titrations, other than a rough titration, to the nearest 0.05 cm^3, for performing sufficient titrations and for obtaining two titres within 0.10 cm^3. Most candidates scored well in this section.

Two accuracy marks were available from a comparison of the Examiner derived "best" scaled average titre and the scaled titre for the Supervisor results. Within most Centres the range of 0, 1, or 2 marks were awarded.

(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".

(c) Unlike the old paper 3 there was not a mark for each step of the calculation. Two marks only were awarded for chemical arithmetic in the first four steps of the calculation. Each chemical error led to the loss of one of these two calculation marks.

One further mark in the section was awarded for showing working in each step and one mark for working to sufficient significant figures (3 or 4 sf in the final answer to each step). The final mark was for expressing, correct to 4 significant figures, the concentration in g dm^{-3} of ammonium iron(II) sulphate in **FB 1**.

Most candidates showed working in all of the steps attempted. Many candidates failed to work to 3 or 4 significant figures – a few gave too many significant figures but the majority falling into this category showed only 2 significant figures. Many candidates gave 3 or 4 significant figures in the first two steps of the calculation but reverted to 2 significant figures in step 3 when calculator displays changed from standard form to a simple decimal form.

For many candidates the first chemical error was seen in step 4 when introducing a factor for the dilution of the ammonium iron(II) sulphate.

(d) Very few candidates were able to suggest heating the distilled water to expel dissolved air or as an alternative to describe storage of the water in a sealed container with no space for air over the water.

(e) It was disappointing to note how many candidates are unaware that the smallest division on the burette scale is 0.10 cm^3 and the estimated error when reading the scale is half this value – 0.05 cm^3.

(f) As two burette readings are taken in obtaining a titre and each has an error of ±0.05 cm^3 the estimated maximum error is 0.10 cm^3. Many candidates correctly calculated the maximum error.

(g) In comparison very few candidates were able to explain how reading the burette twice can lead to no error in the titre. Many candidates thought that the error was eliminated by averaging titre values or that an error of +0.05 cm^3 cancelled an error of -0.05 cm^3.

A small number of candidates were able to explain that the error had to be "in the same direction" on each occasion. (Both +0.05 cm^3 or both -0.05 cm^3).

Question 2

(a) Some very involved calculations were seen usually from weaker candidates. About 50% of candidates were able to calculate 10.08 g as the mass of sodium hydrogencarbonate required.

(b) Candidates were required to record their results in an appropriate format. Marks were awarded for recording in a table all of the weighings and temperature measurements, and the change in temperature; putting data for each of the experiments in a single table; correctly labelling rows/columns including the appropriate unit and for recording all weighings consistently to at least 1 decimal place and all temperature measurements to 1 decimal place.

Many candidates omitted one or both of the following:
the mass of tube + residual mass of **FB 5**;
units – where units were not included in column headings, every individual reading required the appropriate unit;
Temperatures were often recorded to whole numbers only or with 2 decimal places.
Weighings were generally recorded consistently to 1, 2 or 3 decimal places depending on the balance provided by the Centre.

For a single table to be rewarded, no "label" should be repeated. The following is a single table.

	experiment 1	experiment 2
mass of empty tube /g		
mass of tube + **FB 5** /g		
mass of tube + residual **FB 5** /g		
initial temperature /°C		
final temperature /°C		
change in temperature, ΔT /°C		

The following is <u>not</u> a single table:

	experiment 1			experiment 2
mass of empty tube /g		mass of empty tube /g		
mass of tube + **FB 5** /g		mass of tube + **FB 5** /g		
mass of tube + residual **FB 5** /g		mass of tube + residual **FB 5** /g		
initial temperature /°C		initial temperature /°C		
final temperature /°C		final temperature /°C		
change in temperature, ΔT /°C		change in temperature, ΔT /°C		

The Examiners corrected any errors in subtraction in the results table and calculated ΔT for each experiment. One accuracy mark was given for the consistency of the candidate's own results and one accuracy mark for the consistency of the candidate with the Supervisor. A full range of 0, 1 and 2 marks was seen.

(c) This section contained a very simple calculation, using the expression provided. Many candidates calculated a correct numerical value in kJ mol^{-1} but failed to give the positive sign denoting an endothermic reaction.

Question 3

(a) Many candidates failed to take notice of the introduction to the question where it was stated that there would be a need to remove traces of coloured solutions from the silver halide precipitates formed. Candidates were asked to list procedures as well as observations. The Examiners expected to see reference to filtering or decanting the solution to obtain the precipitate (one mark) and washing the precipitate free of the coloured solution (one mark). Very few candidates mentioned filtering or washing the precipitate. As a consequence the silver chloride precipitate formed in **FB 6** (containing Fe^{3+}(aq)) was often reported as a cream coloured precipitate. Residual cations also caused considerable problems when aqueous ammonia was added to the silver halide precipitates.

A number of candidates chose lead nitrate as their second reagent. This was an inappropriate choice as one or more of the solutions contained a sulphate or sulphite ion.

Most candidates were awarded the tabulation mark, the mark for the selection of silver nitrate and the mark for the selection of ammonia when added to the silver halide precipitates formed. Correct observation and deduction marks were often obscured by the cation contamination. Deductions were marked, error carried forward, from the recorded observations.

(b) Most candidates selected barium chloride as the first reagent to test for a sulphate or sulphite. The Examiners expected use of this reagent to be followed by the addition of hydrochloric or nitric acid to test the solubility of the precipitate in the acid. A significant number of candidates, however, added sulphuric acid and concluded that a sulphate was present as the precipitate formed with barium chloride was insoluble in the acid added. Where sulphuric acid was added after the formation of a white precipitate with barium chloride a maximum of one mark from the three available was allowed in this section. Candidates who added an unspecified acid were treated in the same way as those who added sulphuric acid.

Some candidates chose barium chloride as one reagent and lead nitrate as the other. Lead nitrate was an inappropriate selection as at least one of the solutions contained a halide ion.

(c)   Most candidates tabulated the observations with aqueous solutions of sodium hydroxide and ammonia (1 mark) and added the reagent to excess whenever a precipitate was observed (1 mark). Two observation marks were available. Most candidates obtained correct observations for **FB 6** with both sodium hydroxide and ammonia (1 mark). Very few candidates obtained the correct observation with **FB 7**. The formation of a green precipitate with both reagents was a common incorrect observation. Chromium(III) ions give a distinctive grey-green precipitate with each reagent.

Few candidates gave correct observations with **FB 8**. With the specified concentrations of the unknown chemicals and the reagents supplied, **FB 8** should have given a blue precipitate insoluble in excess in each of the reagents. Many observations appeared to have been recorded to fit a conclusion of copper(II) ions, the blue precipitate with ammonia being soluble in excess of the reagent to form a dark blue solution.

(d)   Two marks were available in this section – the first for identifying Fe^{3+} and Cr^{3+} in **FB 6** and **FB 7** respectively. Iron(III) was frequently identified with supporting evidence but the incorrect observations for chromium(III) caused the mark to be unobtainable.

The second mark was for commenting on the transition nature of the cation in **FB 8** from the varied colour of the precipitates. Very few candidates commented on the formation of a blue precipitate in a "pink" solution. Some candidates were able to state that the ion contained in **FB 8** was cobalt(II) but they failed to answer the question as to the nature of the cation.

15

CHEMISTRY

General comments

This was the first year of the new syllabus, and this paper has changed its content, although not its style. The paper total is now 100 marks, of which 70 (comprising **Questions 1** to **6**) were devoted to examining the Core syllabus (an increase of 10 marks from previous years). The other 30 marks (**Questions 7** to **9**) examined the Applications of Chemistry section of the syllabus, which replaces the Options. In general candidates coped well with the new aspects of the syllabus, although the last question, which depended on more applied skills, caused some difficulty. **Question 1 (d)** showed up gaps in candidates' experimental knowledge, and in general the two Inorganic questions, **Questions 3** and **4**, were very poorly answered. Inorganic Chemistry still seems to be the least popular section of the syllabus, receiving less attention by both teachers and candidates than does the Organic section.

Most candidates seemed not to be too troubled by a lack of time to finish the paper. However, it was sometimes difficult to decide whether candidates had left blanks in the last two questions because they had run out of time, or because their understanding was lacking.

There were several examples of candidates losing marks by not reading the question carefully enough, and not thinking precisely as to what they were being asked to do. This was particularly true of **Questions 7** and **9**.

Answers to numerical calculations

1   **(c)**   lattice energy = -2730 kJ mol^{-1}

Comments on specific questions

SECTION A

Question 1

(a)   Most candidates scored well here, although a surprising number omitted the salt bridge. The main marks lost were for not specifying the concentrations of solutions (1 mol dm^{-3}) and the temperature (25 $^{\circ}$C or 298K).

(b)   The anode products expected were chlorine and oxygen for the concentrated and dilute solutions respectively. Quite a number of candidates suggested chlorine for both solutions, or reversed the products (i.e. suggesting oxygen for the concentrated solution), or even suggested hydrogen. At the cathode, zinc would be produced from the molten salt, and hydrogen from the dilute solution. Zinc or hydrogen were equally acceptable for the concentrated solution (the product that actually forms depends on the material used for the cathode).

(c)   Three marks were available for this calculation of lattice energy. Although only the better candidates scored full marks, many were able to gain one or two marks as long as clear working was shown. The most common errors were not multiplying the electron affinity by two, omitting the Cl-Cl bond energy term (244 kJ mol^{-1}, equivalent to two $\Delta H^{\ominus}_{at}$ for chlorine), dividing the 244 by two, omitting either the first or second ionisation energies for zinc (or both), or mixing up the signs for the various terms.

(d)(i) In general, answers to this part were very disappointing, and clearly showed that candidates had not had any experience of performing practical experiments of this nature. The general principle expected in the answer was to use the given spectra to decide that the reaction could be followed using a colorimeter (NOT a **c**alorimeter) or spectrophotometer, measuring the absorbance at a wavelength of 500 nm. For given concentrations of zinc ions and PAR, the absorbance would be measured at set intervals of time, and the rate calculated by measuring the initial gradient of the absorbance/time graph. The experiment should then be repeated for different concentrations of zinc, and the initial rates again measured. Finally, plotting these rates against the (Zn^{2+}) would show the rate dependence.

Often candidates attempted to use a titration method, without any suggestion of quenching or "freezing" the reaction. Even if the reaction were quenched, titration against strong alkali would not distinguish between the $2H^+ + 2$ phenolic OH groups on the right, and the 4 phenolic OH groups on the left of the equation.

(d)(ii) Candidates generally answered this part well. Either $FeCl_3$ (it needed to be **neutral** or **aqueous)**, giving a violet/purple colour, or bromine (it needed to be **aqueous**, i.e. bromine water), turning colourless or giving a white precipitate, were acceptable. Some candidates incorrectly suggested sodium metal or sodium hydroxide, which give ambiguously similar results with carboxylic acids and/or alcohols.
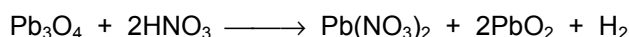
Question 2

(a) Most candidates scored the mark for this equation, although a number forgot to add the "½" in front of the O_2.

(b) The trend was well-known, and many candidates correctly interpreted it in terms of the increasing radius (or consequent decreasing charge density) of the **cation** causing less polarisation **of the (nitrate) anion**. The most common reasons for candidates losing marks were either to describe the increasing radius of the *atom* rather than that of the ion, or not specifying that it was the *anion* that was suffering less polarisation (or distortion).

(c) Many candidates seem not to have been taught this new section of the Core syllabus, namely the interpretation of mass spectra in terms of *molecular fragments*. The most common answer for the fragments formed from gas **A** was $16 = NH_2^+$, $17 = NH_3^+$ and $18 = NH_4^+$ (in which case, why were there no reported peaks at m/e 14 and 15, corresponding to N^+ and NH^+?) Isotopes of oxygen $(^{16}O, {}^{17}O, {}^{18}O)$ also appeared. Candidates should have been aware that the ammonium ion, being part of an ionic compound, cannot be a component of a **gas** at reasonable temperature. Only the very best candidates appreciated that the species O^+, OH^+ and H_2O^+ were responsible for the three peaks. Identification of (most of) the 5 peaks in the mass spectrum of gas **B** proved easier: N^+, O^+, N_2^+, NO^+, N_2O^+. The most common errors here were to suggest $16 = NH_2^+$, and $44 = NO_2^+$. Few candidates seemed to work backwards: having gleaned that **B** was N_2O, taking that formula away from NH_4NO_3 gives H_4O_2, which does not contain any nitrogen (hence NH_2^+ etc. is incorrect), but is merely 2 x H_2O.
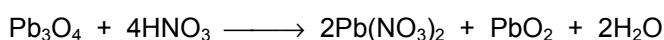
Question 3

(a)(i) These two equations were intended to be easy, but quite a number of candidates suggested that lead metal was a product of the heating of PbO_2, or that O_2 was needed on the left hand side of the $PbO_2 \rightarrow PbO + \frac{1}{2}O_2$ equation. It is a common misconception that any reaction which takes place on heating, automatically implies the involvement of oxygen from the air.

(ii) This was another straightforward question, requiring only the statement that, based on these two reactions, the +2 oxidation state becomes more stable (relative to the +4 state) down the group.

(b)(i) Most candidates deduced that the oxidation states were +2 and +4 (although +1, +3, +5 and +8 were seen in answers) but not all of them then went on to work out the ratio (+2:+4 = 2:1). Some quoted the ratio the wrong way round.

(ii) A surprisingly large number of candidates merely suggested that Pb_3O_4 decomposed into $PbO + PbO_2$, despite their having written the equation for the thermal decomposition of PbO_2 in part **(a)(i)**.

(iii) Many candidates did not take the colour hint, or referred back to the question stem, and produced PbO or Pb metal as the co-product. A popular co-product was also hydrogen, the most common equation being as follows:
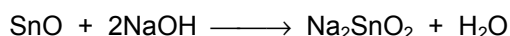
$$Pb_3O_4 + 2HNO_3 \longrightarrow Pb(NO_3)_2 + 2PbO_2 + H_2$$

The correct equation:

$$Pb_3O_4 + 4HNO_3 \longrightarrow 2Pb(NO_3)_2 + PbO_2 + 2H_2O$$

was produced only by the better candidates.

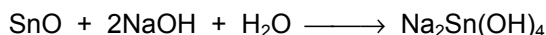**(iv)** Many candidates scored well here: Pb(II) being more basic than Pb(IV) as evidenced by the reaction of PbO with nitric acid to form a salt, whereas PbO_2 remains.

(c) Various possibilities were accepted for this equation, ranging from the simplest ionic equation:

$$SnO + H_2O + OH^- \longrightarrow Sn(OH)_3^-$$
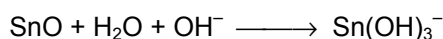
to the full molecular equations:

$$SnO + 2NaOH \longrightarrow Na_2SnO_2 + H_2O$$

or

$$SnO + 2NaOH + H_2O \longrightarrow Na_2Sn(OH)_4$$

The first (ionic) equation turned out to be the most popular.

Question 4

The whole of this question was poorly answered by the majority of candidates. Perhaps the inclusion of transition metals in the Core syllabus took some Centres by surprise, and candidates had not been well prepared for it.

(a) A clear syllabus learning outcome (9.5(k)) is to *describe the shapes and symmetries of the d orbitals*. Very few answers showed the "4-leaved clover" shape of a typical d orbital, and if the Examiners had insisted on the inclusion of the "doughnut" ring around the middle of the dz^2 orbital very few candidates would have scored even (1) mark here. The most common diagram was that of a dumb-bell, which was generously taken as meaning a dz^2 orbital. This was often repeated along a different axis (scoring zero, being a repeat of the dz^2 orbital already drawn). Very few candidates realised that the d_{xy} orbital had to be drawn **between**, rather than along, the axes.

(b) Most candidates knew that the 2-orbital group had the higher energy, but few explained adequately the reason for this. Some did point out that the ligands contained lone pairs of electrons, but the repulsion between these lone pairs and the d-electrons in the orbitals pointing along the axes was only very rarely mentioned.

(c) A significant number of candidates scored the marks in **(i)**, but fewer than expected. The most common error was to reverse the colours, possibly through thinking that the spectra were showing the emission rather than the absorption of light. Another common error was to include colours other than the four given as alternatives. Thus "violet" and "orange" were seen. Solution **C** will appear red because the violet, blue, green and most of the yellow is being absorbed. Solution **D** will appear blue because the red, yellow and green are being absorbed.

In **(ii)** although candidates often chose the correct complex (**C**), the reason was either wrong or not clear. Many candidates thought the reason was because the absorption maximum was higher (on the y-axis) rather than the wavelength of maximum absorption being lower than that of **D**. Other candidates were not clear in their explanation, writing that "**C** absorbs higher energy photons", without using Planck's equation (or a verbal equivalent) to relate the energy of the photon to its frequency.

Question 5

This question was the higher scoring of the two organic questions, and often produced the most marks in the whole paper.

(a) The most common error was to use Cl_2(aq) for reaction I and/or II. In both cases the chlorine needs to be anhydrous. The usual variety of halogen carriers (Lewis acids) was accepted for I: $AlCl_3$ or $FeCl_3$ being the most common. Note that $FeBr_3$ (quoted by some candidates) would not work: the Cl_2 would oxidise the Br^- ions to Br_2, and bromination would result. The $KMnO_4$ (**NOT** $K_2Cr_2O_7$) for reaction III needed to be in acidic or alkaline solution. The most popular inorganic acid chlorides used for IV were PCl_3, PCl_5, $SOCl_2$.

(b) Reaction I is an *electrophilic substitution* reaction, whilst II is an *oxidation.* Most scored well here.

(c) Compound **H** was $C_6H_5CH_2CN$, and step V required heating with NaCN (or KCN, but **NOT** HCN) in ethanolic solution. A variety of reducing agents was accepted for step VI: H_2 + Ni/Pd/Pt; $LiAlH_4$ (but **NOT** $NaBH_4$); Na + ethanol.

(d) Most candidates scored at least three marks for the table, but few scored six marks. Compound **E** is unreactive with both reagents, and **F** does not react with cold water. With hot NaOH, **F** produces $C_6H_5CH_2OH$. Compound **G** produces $C_6H_5CO_2H$ with cold water and $C_6H_5CO_2Na$ with hot NaOH (a surprisingly large number of candidates incorrectly wrote this as C_6H_5CONa).

Question 6

This was intended to be a more difficult question than **Question 5**, and it performed its function of discriminating the good from the weaker candidates well. A few full-mark answers were seen, with more in the six to eight mark bracket, and the majority scoring two to four marks.

(a) Most candidates scored the first mark, but very few correctly calculated that there were 5 chiral centres in the molecule. Most claimed there were only 2, and some claimed there were 8, assuming that the left hand ring was a cyclohexane rather than a benzene ring.

(b) Candidates were expected to include **both** oxygen-containing groups in each formula, even if the second –OH group had not reacted. One mark was deducted if a candidate had failed to do this.

(b) (i) Sodium reacts with both –OH groups, producing –ONa groups. A mark was deducted if the written formula implied that it was the sodium that was joined to the ring (thus on the bottom left-hand ring, the product should have been written as NaO-*ring*, NOT ONa-*ring*).

(ii) Aqueous bromine will replace 1, 2 or 3 hydrogen atoms in the phenolic ring with bromine atoms. No other reaction will occur. Several answers had bromine atoms attached to the junctions of the aromatic ring to the second ring, producing 5-valent carbon atoms!

(iii) NaOH(aq) will only react with the phenolic –OH, leaving the secondary alcohol unchanged.

(iv) Ethanoyl chloride will react with both –OH groups, forming ethanoyl esters.

(v) $K_2Cr_2O_7$ will oxidise the secondary alcohol to a ketone, and leave the phenolic –OH unchanged. Many candidates included an extra carbon here, suggesting the product was *ring*-CO_2H.

SECTION B   **Applications of Chemistry**

Question 7

(a)(i)   The first part of this question combined parts of the Core syllabus *(Section 10.8)* with the Applications *Section 11.2(a)*. Most candidates scored well here. Possible points could have included the following: addition polymers require a C=C double bond in the monomer; the empirical formula of an addition polymer is the same as the (sum of) its monomers; condensation polymerisation produces a small molecule such as water as well as the polymer. Some candidates claimed that addition polymerisation requires only one sort of monomer, whereas condensation polymerisation needs two different monomers. Addition copolymers such as styrene-butadiene, and condensation polymers such as nylon-6 are proof that this is not necessarily so.

(ii)   Most candidates scored at least one mark here, usually for showing the –CO-NH- peptide link correctly. Examiners were surprised at the number of candidates who drew the structure of gly-ala rather than ala-gly. This carelessness in reading the question forfeited a mark.

(b)   The expected answers were **X** = deoxyribose; **Y** = phosphate; **Z** = thymine. Common errors were not to specify **deoxy**ribose (or even to state merely that **X** was a pentose sugar); mixing up the deoxyribose and the phosphate blocks; and stating that **Z** was a nitrogenous base, without specifying which one.

(c)(i)   The majority of candidates correctly translated the triplet codes into the corresponding amino acids and start/stop instructions, although a significant number forfeited a mark by thoughtlessly including the word "stop" in their amino acid sequence. (This was another case of not reading the question carefully enough, or not thinking about what it required for an answer), Either the pentapeptide met-ser-arg-asp-gly or the tetrapeptide ser-arg-asp-gly were accepted as correct.

(ii)   Several candidates forgot that the last three bases were the "stop" codon, so having correctly deduced that the 13th base was part of the penultimate triplet, they then claimed that it was the penultimate amino acid asp, rather than the last one, gly, that was replaced by trp.

(d)   There was a variety of answers produced here, some of which tested the examiners' own knowledge of genetically-caused diseases. Apart from the most commonly quoted examples of sickle cell anaemia, haemophilia and cystic fibrosis, examiners saw references to thalassemia, Huntingdon's syndrome, Down's syndrome, crying cat disease and retinoblastoma. The first mark in part **(ii)** was for a suitable explanation in terms of amino acid deletion or substitution producing an incorrect protein, and the second mark for describing the consequence of this, e.g. a change in the 3D structure, or the activity of an enzyme, or the physiological result of the specific disease mentioned in part **(i)**.

Part **(d)** was generally well answered and candidates often showed a good knowledge of their chosen disease.

Question 8

(a)   A correct answer to this question required the candidates to mention that

- in low pH/acidic solutions the glycine molecule is protonated to the cation $NH_3^+CH_2CO_2H$ and in high pH/alkaline solutions it is deprotonated to the anion $NH_2CH_2CO_2^-$
- the anion will move towards the anode (positive electrode) whereas the cation will move towards the cathode (negative electrode)

Only the better candidates mentioned all these points, and many answers demonstrated a less than complete understanding of the factors involved in electrophoresis.

(b)   In **(i)** most candidates correctly deduced **Q**, but some failed to give the reason for their choice, namely that the molecule of **Q** must have an overall charge of zero, because it did not move during electrophoresis. The vast majority of candidates scored the mark in **(ii)**, pointing out that the larger molecule **R** would travel more slowly than the smaller molecule **S**.

(c) The correct answer to **(i)** – water associated with the cellulose molecules in the filter paper – was given by relatively few candidates.

Most candidates correctly plotted the five points in **(ii)**, but there were some who had reversed the axes, and there were others who had little understanding of two-dimensional chromatography, and plotted two sets of points, one along each axis. There were also some graphs containing 10 points off the axes, at fairly random coordinates. Parts **(iii)** (=**D**) and **(iv)** (=**C**) were well answered.

Question 9

(a) In general this part was poorly answered. Many candidates described the differences in the *structures* of graphite and buckminsterfullerene , i.e. merely describing in words the diagrams given on the question paper, rather than suggesting differences in their *properties*. In many ways this question just required an application of the "core" knowledge of the properties of macromolecular and simple molecular systems. Thus graphite has a higher melting point, a higher density and a lower solubility than buckminsterfullerene. More specific properties are that graphite conducts electricity whereas buckminsterfullerene does not (although it is a good conductor of *heat*, evidently); graphite is slippery or is used as a lubricant, because the layers can slide over each other (references to the possible slippery nature of buckminsterfullerene due to its "molecular ball bearing" shape could also have scored a mark); buckminsterfullerene molecules can trap atoms within themselves. There was some confusion between the properties of individual buckminsterfullerene molecules and the properties of the bulk material. Thus although the individual molecules may well be "harder" than diamond (i.e. the bonds within the molecules may be stronger than the C-C bonds within diamond), the bulk material will be quite soft, due to only weak van der Waals forces between the molecules.

(b) In this section candidates were expected to relate the shapes of the two structural forms to the shape of a test tube. Thus the walls of the tube would be made from a sheet of graphite rolled up into a cylinder, and the closed end would be **half** of a buckminsterfullerene molecule.

(c) Most candidates correctly deduced that the nano-particles would **reflect** the sunlight away from the skin, but very few suggested the reason – that the particles are similar in size to the wavelength of UV light.

CHEMISTRY

General comments

This was the first of the new format A2 "practical" papers. Many candidates had been well prepared for planning, analysis and evaluation but many others scored few marks on the paper as a whole. There was a very wide distribution of marks.

Comments on specific questions

Question 1

Planning of an experimental method requires practical experience of the techniques to be employed. Many candidates in planning this rate of reaction experiment ignored timing completely which raises the question of whether they had ever carried out a rate experiment in a laboratory.

(a)   In this section many candidates failed to mention collisions, simply stating a relationship between the concentration of the acid and the rate of reaction or between temperature and the rate of reaction. The Examiners were looking in part **(i)** for increase (in frequency) of collisions (between particles from the acid and the magnesium) when the acid was more concentrated. No penalty was applied for describing molecules of hydrochloric acid.

Part **(ii)** was generally better answered with reference to more energetic collisions or a greater proportion of the collisions exceeding the activation energy.

More able candidates gave a good explanation in each section.

(b)   Most candidates were able to state that the concentration of the hydrochloric acid was the independent variable. Some candidates gave volume of acid rather than concentration.

(c)   The majority of candidates chose the size/mass/length of magnesium (ribbon) to be used. The total volume of the acid solution was also an acceptable answer.

A small number of candidates did not appear to understand the meaning of independent variable (see syllabus) and gave length of magnesium ribbon in **(b)** and concentration of acid in **(c)**.

(d)   The design of the laboratory experiment.

This is an acquired skill to be developed from practical experience in the laboratory. The Examiners encourage Centres to discuss the design of experiments at every possible opportunity in the course of teaching the syllabus - e.g. when issuing a teacher-designed work sheet including the instructions for an experiment the students are about to carry out. A few minutes discussing why the experiment is to be done in the way described will develop the skills for planning experiments. This in addition to any specific planning exercise.

Seven marking points were included in the plan.

(i) Candidates were asked to list the apparatus to be used in the experiment. A diagram was accepted as an alternative to the list. Many candidates did not obtain this mark as there was no reference anywhere in the experimental description to a stop-clock or other instrument for measuring time.

(ii) A mark was given for carrying out a sufficient number of experiments with different concentrations of acid. The Examiners were looking for a minimum of 5 different concentrations of acid to enable a graph to be drawn with some confidence as to its shape. Many candidates who were vague as to the concentrations to be used did score this mark by indicating the number of experiments to be carried out in the table of results prepared in **(e)**.

(iii) Candidates were asked to show how they would control the independent variable and ensure its value had been measured accurately. Examiners were looking for the use of measuring cylinders, burettes or pipettes in <u>diluting</u> the acid supplied. A number of candidates gave a good description of preparing each diluted solution in a graduated (volumetric) flask.

Some candidates opted to increase the concentration and consequently sacrificed this mark.

(iv) The marking point was for an appropriate measure of time. Examiners were looking for measurement of the time taken to collect a fixed volume of gas or the measurement of the volume of gas evolved in a fixed time. Candidates who recorded the volume of gas given off at regular intervals of time were awarded this mark.

A large number of candidates timed until reaction had stopped. Another large group of candidates made no reference to timing at all and simply recorded the volume of hydrogen given off when reaction ceased.

It was clear that some candidates, who did score this marking point, had little or no experience of the reaction of magnesium ribbon with hydrochloric acid. They dropped a small length of the ribbon into the acid and timed the gas produced in 10 minutes, the method employed was correct but the reaction would have been over long before the specified 10 minutes.

(v) The marking point was concerned with the <u>method</u> of control of other variables. Any reference to control of temperature by using a water bath, or maintaining a constant total volume of diluted acid scored this mark as did reference to measuring a constant amount of magnesium where this had been given as the variable to be controlled in **(c)**.

(vi) The Examiners were looking for an appropriate range of acid concentrations to use in the experiment. The mark was awarded where the final concentration was at least half of the initial concentration used. Many candidates who used fewer than five different concentrations (point **(ii)**) were awarded this mark for range of concentrations used.

(vii) In many plan questions from the old paper 5, candidates were asked to show how they would mix reagents without loss of gas from the apparatus. Many candidates were therefore well drilled in the use of "divided flasks", placing one reagent in a small container inside the reaction vessel, suspending one reagent when assembling the apparatus etc.

In this paper the Examiners did allow the addition of acid through a tap funnel or thistle funnel but would point out that the method described would be unlikely to provide any meaningful results.

Candidates should appreciate that the addition of acid through a funnel in a rate experiment is inappropriate as:

- Acid is unlikely to run into a sealed system consisting of a flask connected to a gas syringe or a flask delivering gas for collection over water and the reaction would not start.

- Assuming the acid <u>would</u> run into the flask, the total volume of the acid must be quickly mixed with the magnesium, which would not be possible through a funnel. This is also a problem when magnesium is placed inside a test-tube inside the flask, a limited amount of acid comes into immediate contact with the solid.

- The acid run **into** the flask would displace an equivalent volume of air from the apparatus.

(e)   The majority of candidates did not include a column for rate of reaction in the table drawn up to record the results of the experiment. A column listing concentration of acid was allowed providing a dilution had been accurately described in **(d)** otherwise columns showing volume of acid and volume of water were required. Most candidates obtained the mark for correct units in the table. The third mark for the analysis of results did require rates to have been calculated, a comparison of times for collecting a fixed volume of gas, or comparison of volumes of gas collected in a fixed period of time to be explained.

(f)   Most candidates stated that the temperature would be altered but failed to say how they would alter the temperature (water bath) or that the concentration of acid must remain constant.

Question 2

(a)   Most candidates correctly calculated two or three of the masses of mercury chloride, mercury and chlorine. Many candidates failed to show the equation for the subtraction, e.g. mass of mercury /g (C-A).

The table gave experimental results – using a balance capable of reading to 0.01 g. All subtractions were expected to show the same precision of measurement. The mass of mercury used in experiment 4 needed to be shown as 1.50 g and not as 1.5 g. A small number of candidates gave 3 decimal places for the "subtractions" – a degree of precision that could not be justified.

(b)   Where the mass of mercury chloride was one of the values plotted the Examiners expected to see it plotted on the x-axis as the independent variable in the experiment. Many candidates plotted mass of mercury chloride on the y-axis. Each axis needed to be labelled with the identity of the substance plotted and the unit. The majority of candidates selected scales that were easy to use but some chose awkward scales that required the use of a calculator when checking the positioning of points on the graph paper. The Examiners expect to see points plotted over more than half of the length of each axis and an easily used scale selected.

The plotting of the points for experiments 1,4 and 7 was checked. Points were accepted as correctly plotted if they were within ½ of a small square in either direction of the point as plotted by the Examiner providing the point was <u>in</u> the appropriate small square of the graph paper. A value such as 0.43 g of mercury in experiment 1 was not correctly plotted if placed on a graph paper line corresponding to 0.40 g of mercury. Similarly 1.40 g of chlorine in experiment 7 was not correctly plotted if "off" a graph paper line representing 1.40 g of chlorine.

The majority of candidates drew a straight line through the points but many had not considered whether (0,0) was a valid point on the graph and did not draw the straight line through the origin. A significant number of candidates did not take sufficient care when drawing a line passing through the origin – the intention was clear as the line passed very close to the origin but not through it.

(c)   Most candidates indicated clearly any points they considered to be anomalous. The Examiners expected the point plotted for experiment 4 to be among these points. Whichever graph was drawn (Hg v HgCl_x Cl v HgCl_x Hg v Cl or   Cl v Hg) points 4 and 7 should have shown the greatest deviation from the straight line drawn.

Many candidates correctly identified potential errors in the experiment, which included loss of mercury when rinsing the metal formed, or weighing mercury that was not dry (water or propanone). The explanation needed to be correct for the points identified – points to one side of the line drawn represented a loss of mercury those on the other side an apparent "gain" of mercury or loss of chlorine. Vague explanations such as errors in weighing were not accepted.

(d)   A minority of candidates were awarded this mark. Many candidates referred to greater accuracy when weighing the solid in experiment 8 but missed the point that the balance error is a constant regardless of the mass measured. It is the % error that is far less significant for experiment 8.

(e)   A significant number of candidates failed to draw construction lines on the graph. Very often the values of a point that had been plotted were used in this section. This was acceptable for the second mark in the section providing the point actually lay on the line drawn.

Many candidates calculated the gradient of the line drawn and assumed this was the value of x in the formula of mercury chloride.

Many good and varied calculations were seen. Candidates who had plotted the masses of mercury and chlorine had the easiest calculation. Those who plotted the mass of chlorine against the mass of mercury chloride had the most involved calculation. Many candidates were able to solve

$$\text{gradient} = \frac{35.5x}{(201 + 35.5x)} .$$

The majority of candidates, in calculating the value of x, reduced numerical values in the steps of the calculation to 1 or 2 significant figures only – giving a very approximate answer for x that had consequences in the next section.

(f)   This section started by asking candidates to "consider the data you have processed and the graph you have drawn". Many candidates gave answers that referred to neither the data processed nor the graph drawn but made general comments about likely errors in the experimental method as described, or the poisonous nature of mercury.

Those who did comment on the graph frequently referred to many anomalous points when the graph drawn showed the majority of points very close to the straight line. It would appear that many candidates expected any point that was not anomalous to lie exactly on the line – a situation unlikely to be achieved with experimental data. The Examiners were looking for two of the following three points as justification that the experimental was suitable for determining the formula of mercury chloride: straight line graph; passing through the origin; the majority of points close to the line.

The second mark in this section was for commenting on the near integral value calculated for x in **(e)**. Candidates who worked to 1 significant figure in **(e)** often produced ratios that were not close to 1:2. Working to 3 significant figures with a well- drawn graph a ratio such as 1:2.04 could be obtained.

Where points clearly did not fit the line or a non-integral value of x with sufficient significant figures was calculated marks in this section were awarded for a reverse argument.

(g)   Silver nitrate or lead nitrate was often suggested. Candidates should take care if giving the chemical formula of a reagent – it must be correct. $PbNO_3$ was not accepted.

A significant number of candidates appreciated that they needed to form the insoluble silver or lead chloride but then added silver chloride or lead chloride.