CHEMISTRY

Paper 0971/11
Multiple Choice (Core)

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

General comments

Candidates found this to be an accessible paper overall with many questions showing good discrimination between candidates. A good spread of marks was seen although fewer candidates scored the higher marks. Overall candidates found **Question 1**, **3**, **8**, **21** and **25** to have the least challenge.

Question 5, **6**, **7**, **10**, **17**, **18**, **34** and **36** were most demanding.

Many candidates are making errors in basic skills such as using chemical formulas and determining the type of bond in common elements and compounds. Further practice on the recall and use of common ions is recommended.

In common with previous papers, candidates found sections related to practical work difficult. For example, the colours of acid-base indicators or the question involving the production and testing for ammonia using litmus were not well recalled.

Most of the questions on organic chemistry were challenging.

Comments on specific questions

Question 5

Few candidates answered this question correctly. The question asks for an isotope of the nuclide shown. An atom with the same number of protons but a *different* number of neutrons was required. Most candidates only used the isotope shown and chose **Distractor B**. Approximately a quarter of the candidates chose **Distractor C** or **Distractor D**.

Question 6

This question was not well answered. **Distractor B** was the most common response, but all distractors were commonly chosen. Almost two thirds of the candidates thought potassium iodide had covalent bonds and so shared electrons.

Question 7

Over half of the candidates chose **Distractor C**. Iron(III) oxide is an ionic substance and argon is monatomic so only methane and chlorine contain covalent (electron sharing) bonds.

Question 9

An equal number of candidates chose the correct answer and **Distractor D**. More than one in seven candidates chose **Distractor A** which has both an incorrect symbol for cobalt and an incorrect ratio of cation to anion.

Question 10

This was a demanding question at this level. Candidates were told the M_r of $MgCO_3$. From this they could deduce that 21g is a quarter of this value so the correct answer should be a quarter of the M_r of MgO. This is where most candidates used the atomic number rather than the mass number to calculate M_r and so chose **Distractor B**.

Question 17

Overall the distribution of answers suggests that many candidates were guessing. Many candidates find the recall of indicator colours difficult.

Question 18

Although a small majority of candidates recognised that the test was for ammonium ions rather than nitrate ions, weaker candidates were more likely to think that ammonia would be produced using an acidic oxide and chose **Distractor C**.

Question 19

This question is more challenging than it first appears. Over a third of candidates thought that copper reacts with a dilute acid and chose **Distractor C**.

Candidates should recognise from the name of the salt that the acid must be sulfuric acid. The other compound must contain the copper. **Distractor D**, the non-metal oxide, must therefore be incorrect.

Candidates should know that copper(II) hydroxide is insoluble, so copper(II) hydroxide is not an alkali, so the answer cannot be **Distractor A**.

Question 27

Most of the more able candidates answered this correctly but the least able appeared to be guessing. For those candidates, few recalled that the main ore of aluminium is bauxite.

Question 34

The majority of candidates assumed that ‘compound **Z**’ was an alkene. The formula given matches C_nH_{2n+2} and so **Z** is an alkane. The syllabus describes alkanes as only reacting in combustion or in substitution reactions with chlorine which gives the answer.

Distractor C was chosen by over a third of the candidates overall.

Question 35

The order of the fractions is difficult to recall making this question more challenging. Many candidates appeared to be guessing. Candidates could consider learning a phrase using a ‘mnemonic generator’ to remember the fractions in order.

Question 36

The purpose of cracking is to produce a range of more useful hydrocarbons. This can include alkenes and shorter-chain alkanes used in petrol. **Distractor D** was the most popular option. The word ‘only’ in statement 2 is significant. Because shorter alkanes are produced, statement 2 cannot be correct.

Question 37

Most candidates identified ethene as a hydrocarbon but confused the meaning of saturated and unsaturated. **Distractor B** was the most popular choice. Most candidates knew that ethene is reactive and so **Distractor D** was chosen by few candidates.

Question 38

The precision of measuring apparatus is not well known by some candidates. A 25 cm^3 measuring cylinder would measure to the nearest 1 cm^3 and so 25.0 or 25.5 could be recorded. Only the burette could be used to measure to two decimal places.

Question 40

This question tested both knowledge of precipitation reactions and flame tests. Weaker candidates overall appeared to be guessing with all the options frequently chosen.

CHEMISTRY

Paper 0971/12
Multiple Choice (Core)

There were too few candidates for a meaningful report to be produced.

CHEMISTRY

Paper 0971/21
Multiple Choice (Extended)

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

General comments

This paper had a large number of candidates. The candidates found this to be an accessible paper overall but showing good discrimination between candidates. Many questions were answered correctly by at least half of the candidates overall. As a result. this paper showed a relatively high average mark.

Overall, candidates found **Question 1**, **12**, **14**, **21**, **24**, **25** and **33** to have the least challenge.

Question 7, **9** and **18** had the highest demand.

Many candidates found questions involving numbers or a calculation to be challenging but these questions often showed good discrimination between the most and least able candidates.

Questions related to practical work such as chromatography, preparation of salts or colour changes were not well recalled.

Comments on specific questions

Question 3

Over a third of the candidates chose **Distractor B**. Atoms of ^{1}H do not contain any neutrons and so do not contain equal number of proton, neutrons and electrons.

Question 4

This question discriminated well between the most and least able candidates. The least able were more likely to choose **Distractor C** or **Distractor D**. This question was not anticipated to have a high demand because the answer can be determined by a simple average. It is recommended that candidates check their answer to questions like this by applying their answer to the masses given and matching their value to the A_r given.

Question 7

Over half of the candidates assumed that silicon(IV) oxide is a giant ionic lattice rather than a giant covalent lattice and chose **Distractor A**. Few candidates chose **Distractor B** or **Distractor D**.

Question 8

Most of the more able candidates answered this question correctly. Most of the weaker candidates were more likely to choose **Distractor B**. Candidates should recognise that if both molecules contain 3 carbon atoms but different number of of oxygen atoms, their empirical formulas cannot be identical.

Question 9

Most candidates recognised that the acid was the limiting reactant. Over two thirds of the weaker candidates chose either **Distractor B** or **Distractor C** suggesting that the confusion occurs with the use of stoichiometric ratios rather than the moles calculation.

Question 17

This question discriminated well between the most and least able candidates. The least able candidates appeared to be guessing which shows a gap in knowledge of both the colour of the manganate(VII) ion and the role it plays in organic reactions.

Question 18

Almost a third of the candidates chose **Distractor B**. For 'acid R' and 'acid S' only partial dissociation occurs therefore they must both be weak acids.

Question 19

Few candidates chose **Distractor B** or **Distractor C**. Most of the weaker candidates chose **Distractor D**. Crystallisation is a process used to remove soluble salts from solution. Lead(II) sulfate is an insoluble salt and so crystallisation is not used in its preparation.

Question 28

Nearly all of the stronger candidates overall answered this correctly. **Distractor A** was the most common incorrect answer by the other candidates. Irrespective of the method used, all metals are extracted from the (oxide) ores in a reduction process. Electrolysis is used to extract the more reactive metals.

Question 32

Over two thirds of the candidates chose **Distractor C** or **Distractor D**. Candidates are reminded that petrol is a mixture of hydrocarbons and so it cannot be nitrogen from the petrol that is reacting and that the purpose of the catalytic converter is to remove oxides of nitrogen not to produce them.

Question 39

Almost half of the weaker candidates chose **Distractor D**. Although filtration may occur later, (after the solution is heated to crystallisation point and cooled), it is not required. Only evaporation, to remove the water, is required.

Question 40

Well over half of the candidates chose **Distractor A** or **Distractor B**. For any of the colourless amino acids to be seen a locating agent would be used and if an amino acid was insoluble, it would still be present on the baseline.

CHEMISTRY

Paper 0971/22
Multiple Choice (Extended)

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

General comments

Candidates found this to be a very accessible paper overall although most questions showed good discrimination between candidates. A wide range of total marks were awarded from a low guessing average to a small number of candidates who were awarded full marks. Many questions were answered correctly by over half the candidates. As a result, the average score is higher than in some previous years.

Overall candidates found **Question 3**, **4**, **5**, **7**, **8**, **21**, **25**, **37** and **39** to have the least challenge.

Question 2, **14** and **24** were most demanding.

Questions on organic chemistry were particularly well answered by most candidates whereas questions on enthalpy changes were only answered well by the more able candidates.

Candidates should take care to read each question carefully especially where chemical names are very similar such as ethane/ethene or chlorine/chloride.

Comments on specific questions

Question 2

Just over a third of candidates overall answered this question correctly, with most choosing **Distractor A** or **Distractor B.** Candidates should recognise that the temperature at which the liquid boils is also the temperature at which its gas condenses, so the 'temperature – time' curve should be flat and equal during these two state changes.

Question 11

Over half of the weaker candidates chose **Distractor B** or **Distractor C**, showing confusion of either the substance reduced or the difference between the anode and cathode. Candidates are reminded that cations are attracted to the cathode and that sodium metal could not be formed in an aqueous solution.

Question 14

Distractor D was the most common incorrect answer. The average bond energy is the energy required for a bond to be broken. If bonds are formed, then energy is released, and the sign of the enthalpy change will be negative.

Question 15

This question discriminated well between the most and least able candidates. The least able candidates were more likely to choose **Distractor A** or **Distractor D** suggesting some confusion about the role of a catalyst and the value of the activation energy, E_a.

Question 17

Distractor B was the most common incorrect answer. Candidates should recall that the production of a pure metal from its ore or from a specific compound will be a reduction reaction because metals do not typically show negative oxidation numbers.

Question 19

When describing the dissociation of a strong acid in water, the full reaction arrow '$\rightarrow$' is used. When describing a weak acid the reversible arrow, '$\rightleftharpoons$', is used. The most common incorrect answer was **Distractor B** which shows hydrochloric acid as a weak acid.

Question 23

This question discriminated well between the most and least able candidates. The least able were more likely to choose **Distractor A**. Although the substance would be diatomic, it would be predicted to be a solid if it follows the trend of the other halogen molecules.

Question 24

This question caused a lot of confusion amongst candidates although a third of all candidates overall answered it correctly. The description of the reaction can be broken down into two parts: 'which halogen causes the displacement?' and 'which halogen has been produced (i.e., displaced) from its compound?' The halogen causing the displacement is chlorine and the halogen that is displaced is bromine. Chloride does not cause any reaction here and bromide is not produced.

Question 26

Weaker candidates were more likely to choose **Distractor B** or **Distractor C**. From the information given, the metal which becomes an ion is the more reactive of the two metals. From this, candidates can construct a relative order of metal reactivity but will be left being uncertain how the zinc and tin are ordered, leading to option A as the key.

Question 27

Distractor C was a popular incorrect answer. Zinc is used as both a barrier protector of iron and a sacrificial protector of iron. Provided the zinc is in contact with at least part of the iron, the iron will be protected from corrosion.

Question 40

Negative temperature values often cause confusion, and many candidates chose **Distractor C** or **Distractor D.** Candidates could draw a thermometer and create a rough scale showing the specific values given to help them to identify which are higher than 78°C and which are lower than –114°C.

CHEMISTRY

Paper 0971/31
Theory (Core)

Key messages

- Candidates should read each question carefully, so they are sure to answer the question asked. Repeating the question or vague answers should be avoided.
- Candidates should be able to identify all the elements, ions and compounds named in the syllabus.
- Qualitative and physical tests were poorly recalled and further practice with practical work would be beneficial.
- The word 'temperature' unqualified does not mean heating. If candidates wish to use the word 'temperature', they should qualify it by using 'high' or 'low' or, where relevant, state the values given in the syllabus.
- Syllabus terms for different particles such as atom, ion, molecule, element, compound were used interchangeably by some candidates. Additional work to reinforce understanding of the difference between these terms is recommended.

General comments

Overall, this paper performed well and produced a wide range of marks allowing discrimination between the candidates.

Chemical tests such as those in **Questions 1(e), 2(b)** and **5(a)(iii)**, were not well known and it sometimes appeared that candidates were guessing likely observations such as a white precipitate or litmus paper changing colour. It is recommended that candidates spend more time completing questions of this type in written and in practical chemistry.

Most candidates could interpret information from a table and could balance chemical equations, but candidates should take care with the spelling of chemical names. Chemical formulas containing brackets were not well understood, **Question 3(c)**.

Many answers were too vague to be awarded credit. An adverse effect of sulfur dioxide, carbon monoxide or methane is not 'air pollution' (**Questions 3(b)(i)** and **(ii)** and **Question 8(d)**) and a reaction condition of 'temperature' is insufficient, (**Questions 4(b)(i)**, **4(d)(i)**, **5(a)(ii)** and **6(b)**).

The difference between fractional distillation, simple distillation, cracking and polymerisation is not well understood by many candidates, **Question 4(a)(i) and 4(b)(i)**.

More candidates were able to answer questions about metals, their physical properties and their reactivity.

There are a number of terms in the syllabus which candidates should be able to clearly define or describe, for example the word alloy, **Question 5(b)(i)**.

This paper had several questions requiring candidates to write longer descriptive answers. These include **Questions 2(d)**, **4(b)(i)**, **6(b)** and **8(b)**. Candidates should practice these sorts of questions so that they address all the points of the question using appropriate terminology.

The stages of water treatment for the domestic supply were not well known in **Question 8(a)** and the uses of physical tests such as the measurement of boiling point were not well described, **Question 8(b)**.

Comments on specific questions

Question 1

The question on qualitative analysis, **1(e)**, was not well answered. Most candidates recalled straightforward facts from the syllabus such as the use of aluminium in food containers, **Question 1(g)**, and the main gas present in clean dry air, **Question 1(d)**.

(a) The link between group number and the ion of the elements or the formation of ionic bonds from Group I elements was not well recalled. Many candidates suggested fluorine or magnesium.

(b) Most candidates correctly recalled that iron is extracted in the blast furnace. A common incorrect answer was to suggest aluminium.

(c) Although the majority of candidates answered this question correctly, magnesium was a very common incorrect answer. Although magnesium is relatively soft it is not more reactive than sodium.

(d) This question was well answered with most candidates identifying nitrogen as the main gas in clean, dry air.

(e) Qualitative tests were not well recalled. All the other gases present were chosen, with fluorine being the most popular incorrect answer.

(f) As one of only two elements which are liquid at room temperature and pressure, it was anticipated that more candidates would identify bromine from the list. For this paper, fewer than one third of the candidates chose bromine, with fluorine and ammonia being common incorrect answers. Candidates should be reminded that bottles which may be labelled as ‘ammonia’ in the school laboratory contain an aqueous solution, not pure ammonia.

(g) Most candidates identified aluminium as the element used in food containers.

(h) Although a majority of the candidates answered this correctly, some candidates appeared to be guessing. All of the possible options were seen.

Question 2

This question showed strong discrimination between candidates. The chemical test for chloride ions and the general properties of ionic compounds were not well known

(a) (i) Most candidates gave the correct chemical name for $CaCO_3$. Candidates who performed less well overall tended to construct their own system and named it as ‘calcium carbon oxide’ or ‘calcium cobalt’.

(ii) Candidates should be reminded to give all numerical answers in the decimal format. Some calculators produce answers as fractions e.g. 133/4 which are not accepted.

(iii) The solubility rules are not well known. Although there was a slight preference towards the correct answer, all the other options were frequently chosen.

(b) Only a quarter of the candidates could recall the test for chloride ions. A few suggested the test for chlorine gas but one in seven candidates made no attempt at this question.

(c) Compared with other years, more candidates correctly completed the electron arrangement and the charge of this ion. Common errors were to add an electron to represent the sodium atom or to add extra electrons to the inner shell. A small number of candidates confused the charge with the atomic number.

(d) Candidates frequently confused the individual particle behaviour with bulk properties of liquids. Particles of a substance in the liquid state will slide over each other but only in bulk do liquids have a variable shape and fixed volume. Candidates should take care to identify whether they are answering a particle question or general bulk properties of a substance.

(e) The general properties of ionic compounds were not well recalled. Candidates should know that 'high melting point' and 'high boiling point' are not considered as two separate marking points and together or separately would only gain one mark. A few candidates contradicted 'high melting point' with 'low boiling point' or vice versa.

A significant number of candidates misread the question and named two other ionic compounds rather than two properties.

(f) Most candidates recalled oxygen as the gas essential for aquatic life. Nitrogen and hydrogen were common incorrect answers.

Question 3

Most candidates were able to use nuclide notation to identify the numbers of particles in atoms but the properties of sulfur dioxide was less well known and the use of brackets in the chemical formula, $Al_2(SO_4)_3$ confused many candidates.

(a) (i) This question was not well answered. Most candidates suggested that sulfur is placed in Group VI because it was a non-metal and some thought it was a gas. Some answers which were closer suggested it was because it required two electrons to have a full outer shell rather than describing the number of electrons it has in the outer shell.

(ii) This question was well answered with many candidates gaining full credit. A small number confused neutrons with nucleons.

(b) (i) The source of sulfur dioxide was not well recalled. Most candidates confused the source with an adverse effect and suggested 'acid rain'. A few candidates listed other air pollutants. Candidates should note that 'factories' unqualified is not considered a source of pollutants.

(ii) More candidates answered this question correctly than for **(b)(i)** although a significant number confused the adverse effect with those for other pollutants and some stated 'air pollution' without an adverse effect of the pollution.

(iii) Most candidates balanced the hydrogen atoms. Many appeared to miss the three sulfur atoms on the left-hand side of the equation.

(iv) Although a majority of candidates answered this correctly, a significant number suggested 'ionic', 'metallic' or 'single'. Whilst 'chemical bonding' is correct it is not sufficiently accurate for credit.

(c) The use of a formula with brackets caused significant confusion. Many candidates did not know what they represented and frequently multiplied all the numbers together. Some candidates confused atomic mass and atomic number.

The contribution of aluminium atoms to the relative mass was often correct.

Question 4

Questions on organic chemistry are often found to be demanding. Several questions, **4(b)(i)**, **4(b)(ii)**, **4(c)**, **4(d)(i)** and **4(d)(ii)** were not attempted by ten per cent or more of the candidates. As a result, this topic showed strong discrimination between candidates overall.

(a) (i) The distinction between fractional distillation and cracking confused many candidates. Some candidates were close with 'distillation', but <u>fractional</u> distillation is required.

(ii) Few candidates recalled the use of fuel oil as the fuel for ships or home heating systems. The most common answer was fuel for cars.

(iii) It was anticipated that most candidates would be able to recall the main constituent of natural gas, but the most common answer was carbon dioxide. Ethane and ethanol were not commonly chosen.

(b) (i) When describing reaction conditions, candidates should note that 'temperature' unqualified or 'pressure' unqualified are ambiguous. We do not know whether this means high temperature or low temperature or a specific value. Similarly to **Question 4(a)(i)**, there was significant confusion between cracking and fractional distillation and some candidates described polymerisation.

(ii) Many candidates confused the breaking up of solids and reaction rate with the production of <u>more useful</u> compounds.

(c) Many candidates correctly drew two carbon atoms with a single bond. The most common error was to give only four hydrogen atoms.

(d) (i) Similarly to **Question 5(b)(i)**, 'temperature', 'pressure' and 'catalyst' were all insufficient to answer the question. Some candidates confused fermentation with the catalytic addition of steam to ethene.

(ii) Many candidates gave vague answers to this question. Common answers were 'for medicine', 'for making bread' or 'for alcoholic drinks'. Candidates should note that ethanol is not manufactured separately and then added to other liquids to make alcoholic drinks. Pure ethanol is a poison and so 'use as a beverage' is not a marking point on this paper.

(e) (i) Most candidates answered this question correctly.

(ii) Many correctly identified unsaturation as the presence of the carbon-to-carbon double bond, C=C. A common error was to state 'double bond' without reference to the two carbon atoms. The molecule shown contains a C=O bond which, on its own, would not qualify the molecule as unsaturated

Question 5

Most candidates could interpret the diagram to give a reactivity series and to suggest at least one change which would increase the reaction rate. The test for hydrogen gas was not well known.

(a) (i) Most candidates answered this correctly.

(ii) Most candidates answered this correctly. Similarly to the questions on reaction conditions, some candidates wrote 'temperature', which is ambiguous. Candidates should note that increasing the pressure for a reaction that occurs in aqueous solution does not affect rate. The reactants must be gaseous for this to be correct.

(iii) Qualitative tests were not well recalled. Some candidates confused the use of a lit splint with the flame test. Although it is a common term, 'the pop test' does not describe the action required and credit was not awarded.

(iv) Approximately one third of the candidates answered this correctly. Many candidates did not attempt the question. Some candidates stated 'hydrogen ion' but the question required the formula of the ion.

(b) (i) Candidates confused mixtures with compounds or molecules. Candidates should include the words, 'mixture' 'metal' and 'element' in their answer.

(ii) Most candidates recalled that stainless steel resists corrosion/rusting. A small number suggested properties of metals but not one which would be useful in the manufacture of cutlery for example, some candidates suggested 'ductile' or 'electrical/thermal conduction'.

Question 6

The longer descriptive question in **(b)** was not well answered. Candidates can consider using single sentences as bullet points if it helps them to address each point required by the question. Candidates should avoid repeating the question as their answer.

(a) When writing chemical names, candidates should make their answer as clear as possible. Some candidates appeared to write 'magnesium nitrite', which is incorrect. Other common errors included 'hydrogen', 'carbon oxide' or the formula 'H_2O' or 'CO_2' rather than the chemical name.

(b) Few candidates gained full credit with many simply repeating the bullet points. The first step should be to filter the mixture. Candidates who filtered after heating the mixture (to saturation) were not awarded credit because this would remove more than the excess copper(II) oxide.

Most candidates could recall a method for drying the crystals, but few fully described the idea of heating crystallisation point and then cooling to form the crystals.

(c) (i) Most candidates were able to identify the electrolyte with some consideration given for spelling or other errors of the chemical name. A small number drew ambiguous arrows for the electrolyte such that it was difficult to determine whether they were identifying the crucible, the electrolyte or an electrode. The most common error was to label the wire to the anode rather than the electrode dipped into the electrolyte.

(ii) Candidates should recall that aqueous metal solutions are often used in electroplating and so would not be considered inert.

(iii) A small majority of candidates answered this question correctly. Some candidates gave the products the wrong way around.

(d) Some incorrectly used the density to identify the simple molecules. Candidates should be able to identify low melting point as a property of simple molecules, but some described the values given as 'normal melting points' which is unclear.

Question 7

This question was the most accessible question on the paper with most candidates performing well across each part.

(a) (i) Most candidates answered this question correctly. Few gave Experiment 1 or 3.

(ii) Most candidates could balance the species. A few incorrectly gave 2H rather than H_2 or created an extra oxygen atom to give H_2O.

(iii) It was anticipated that candidates would be able to use the symbols for the reactants and products from Experiment 4 and to label the vertical axis as 'energy'.

(b) This question was answered well by most candidates.

Question 8

The stages of water treatment were not well known and the adverse effects of air pollutants not well recalled.

(a) Few candidates recalled reasons for using carbon in water treatment. Many gave vague answers such as 'to make it pure'. Many were able to describe the use of chlorine in the killing of microorganisms/bacteria. Candidates should note that chlorine does not 'remove' bacteria from the water.

(b) This question required candidates to describe the action of heating and then to measure the boiling point of water. They should then compare the value to the expected value of 100 °C. Many assumed this question was linked to the previous question and suggested heating the water to dryness and checking for residue, which did not answer the question asked. Other common errors included timing how long it takes for the water to boil, descriptions of the boiling point falling when impure or boiling to kill bacteria to make it drinkable.

(c) A majority of candidates recognised that distilled water is either pure or purer than tap water.

(d) This question was not well answered. References to ozone were common and many gave vague answers such as ‘air pollution’, which does not answer the question. Confusion with other air pollutants was common.

CHEMISTRY

Paper 0971/32
Theory (Core)

There were too few candidates for a meaningful report to be produced.

CHEMISTRY

Paper 0971/41
Theory (Extended)

Key messages

- Candidates had difficulties in writing ionic equations.
- Candidates found calculating oxidation number and applying the concept of oxidation number challenging.
- Fizzing, bubbling and effervescence mean the same thing. There is no need to use more than one of these words in any answer.
- Candidates should ensure they understand the meaning of the word 'observations'. For example, 'a gas is produced' or to state the name of a product are not observations.

Comments on specific questions

Question 1

(a) This was answered extremely well. Sulfur dioxide and oxygen were seen very occasionally.

(b) This was answered extremely well. Methane and propane were seen very occasionally.

(c) This was answered extremely well. Methane was seen occasionally.

(d) This was answered quite well. Nitrogen was the most common incorrect answer.

(e) This was answered extremely well.

(f) This was answered extremely well. Nitrogen was seen occasionally, possibly due to confusion with oxides of nitrogen.

(g) This was answered quite well. Propene and graphite were seen occasionally.

(h) This was answered very well. Sulfur dioxide was seen occasionally.

(i) This was answered extremely well. Nitrogen was seen very occasionally.

(j) This was answered very well. Propane and ethanol were seen occasionally.

Question 2

(a) This was answered extremely well. The most common errors were omission of the plus sign for the proton charge; just – and + signs for the relative charges; zero for the relative mass of a neutron.

(b)(i) This was answered extremely well. The most common errors were 19 or 20 electrons for the ion and/or 18 protons for the ion.

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

(iii) Candidates performed poorly on this question. Many candidates referred to the numbers of protons, neutrons and electrons in the isotope. Very few stated that aluminium contains only one isotope. The most common answer was that the nucleon number is equal to the relative molecular mass. This is merely a restatement of the question. 'The isotope has no neutrons' was also seen occasionally.

(c) Candidates found this question challenging. Many chose to give names instead of formulae despite the instruction.

Question 3

(a) (i) Many candidates gave correct concise answers. The most common errors were references to negative ions and intermolecular forces. Candidates often omitted reference to attraction between positive ions and electrons. 'Force' and 'electrostatic' both need to be qualified by reference to 'attraction'. Ionic and covalent bonding were also referred to occasionally.

(ii) The word 'free' is irrelevant and unnecessary in answer to this question. The most common error was to omit reference to movement of electrons. 'Mobile ions' was another incorrect answer that was seen occasionally.

(b) (i) This was answered quite well. Some candidates would benefit from familiarising themselves with syllabus statements about why alloys are more useful than pure metals.

(ii) This was answered quite well. Nickel, tin and iron were common wrong answers.

(c) (i) Many candidates gave answers that omitted observations. The names of substances and tests for gases gain no credit for questions that ask for observations. Many candidates who referred to a blue colour often omitted a reference to solution.

(ii) It was essential to refer to sulfuric acid in answer to this question. 'The reactants had run out' was a common answer that received no credit. Many used the terms 'limiting reactant' or 'excess' which also received no credit. Others incorrectly suggested that the solution would become saturated.

(iii) Copper(II) sulfate was the most common incorrect answer from those who confused filtrate with residue.

(iv) Large numbers of answers named salts, usually copper chloride or copper nitrate, rather than the required bases.

(v) This was answered well. Unsaturated was seen occasionally.

(vi) Several answers gave terminology such as 'collision frequency per unit time increases'. In such cases the phrase 'per unit time' is unnecessary in addition to frequency.

Several candidates suggested that the kinetic energy of particles increased because the concentration of the acid increased; others referred to a change in surface area.

'The number of particles increased' was frequently seen without reference to particles per unit volume. Many suggested particles gain energy or move faster. The number of collisions increasing should have been qualified by reference to frequency.

(vii) This was answered quite well. 'Hydrous' and 'water of crystallisation' were common incorrect answers.

Question 4

(a) This was answered well. The most common incorrect answers showed either two or four shared electrons. A small number of candidates used only dots or only crosses.

(b) (i) This was answered very well. The most common errors were incorrectly stated units and omission of the word 'catalyst' when referring to iron. The catalyst was occasionally named as vanadium(V) oxide.

(ii) This was answered quite well. 2N instead of N_2 was the most common error. H instead of H_2 was seen occasionally.

(c) (i) This was answered very well. The most common error was an incorrect number of oxygen molecules.

(ii) Candidates found this question very challenging. Oxidation numbers without a sign were commonly seen. Candidates should remember to write the sign before the number (e.g., –3) as opposed to the number before the sign (e.g., 3–).

(iii) Many chose to ignore the instruction 'in terms of oxidation number' and chose to write about transfer of electrons or transfer of oxygen instead.

(iv) The formula of nitric acid was often incorrect.

(d) This was answered very well. A common error was to use 24 000 instead of 24.

Question 5

(a) This was answered quite well. 'Concentrations of reactants and products are equal' and 'rates of reactions are constant' were seen occasionally. 'Forward reaction is equal to reverse reaction' was another statement that gained no credit.

(b) (i) This was answered quite well. Advantages as opposed to disadvantages were seen very occasionally. Some described the shift in the position of equilibrium rather than a decrease in yield of methanol.

(ii) This was answered quite well. Candidates need to be aware that a catalyst increases the speed of both reactions in an equilibrium mixture.

(iii) This was answered quite well. 'Endothermic' was the most common incorrect answer. Answers referring to factors other than thermicity were seen occasionally. Some referred to equilibrium shifting.

(iv) This was answered quite well. Some candidates tried to explain why copper had catalytic properties, such as its unreactivity, rather than identify it as a transition element. Some incorrectly chose the term 'transitional element'; others occasionally chose potassium because of its high reactivity.

(c) (i) This was answered very well. Most candidates who gained full credit chose 'same general formula' and 'same functional group'.

(ii) Candidates found this very challenging. $C_5H_{11}OH$, a structural formula, was the most common incorrect answer.

(d) (i) This was answered quite well. The carbon atom in the C=O group of the ester linkage occasionally had more than 4 bonds. Carboxylic acids were occasionally seen.

(ii) Butanol was given almost always. Ethanoic acid was usually correct. Candidates should be aware that all straight chain alcohols containing more than two carbon atoms must contain a number as part of their name.

(e) This was answered quite well. A small number of candidates used proton number instead of relative atomic mass. Some divided the percentages by the smallest percentage. Others over approximated after correctly calculating the number of moles of atoms.

Question 6

(a) This was answered extremely well. 'Noble gases' was the most common wrong answer. 'Halides' was also occasionally seen.

(b) This was answered very well, although fluorine was occasionally spelt incorrectly. 'Tennessine' was the most common incorrect answer.

(c) This was answered quite well. Although the question specified that the colour and state of iodine are those at room temperature and pressure, many candidates described the appearance of iodine as an aqueous solution or in the vapour state. Yellow, blue and brown were often seen as incorrect colours.

(d) (i) Candidates found this extremely challenging. Many attempted to write an ionic equation for a non-existent precipitation reaction. Others attempted ionic half equations. Some candidates wrote the formulae of the halogens as Br_2^0 and I_2^0. It was not uncommon to see the equation on the paper repeated as the answer.

(ii) This was answered very well. Some final answers did not have a sign despite the instruction. Others showed signs on the first two values.

(e) (i) This was answered reasonably well. Some candidates gave answers that omitted observations. Names of substances and tests for gases gain no credit for questions that ask for observations. Some referred to yellow flames and sparks or explosions. A test for hydrogen gas was occasionally given.

(ii) This was answered quite well. Colourless, pink and yellow were seen occasionally.

CHEMISTRY

Paper 0971/42
Theory (Extended)

Key messages

- When drawing organic structures, it is essential that the correct valency is given to atoms. Often pentavalent carbon atoms or divalent hydrogen atoms were seen in **Question 6(e)(iii)**.
- If a single answer is asked for, two (or more) answers should not be given, as incorrect statements may contradict correct answers.
- Candidates should avoid giving answers as fractions to calculations such as **Question 4(c)(iii)**.

General comments

All marks were accessible to candidates and there appeared to be sufficient time for all questions to be answered.

Some candidates overwrote changes to their responses which made them difficult to read particularly if they changed to similar letters or numbers. To cross out and replace responses is recommended to ensure the desired response readable.

Most definitions and terms introduced into the new 2023 syllabus were known, although knowledge and use of oxidation numbers remains a challenge for some.

Comments on specific questions

Question 1

This required candidates to show their knowledge of factual chemistry by providing numerical answers.

Parts **(a)**, **(b)**, **(d)** and **(f)** were very well known with **(c)** proving to be the most difficult.

Question 2

(a) This question required recall of a syllabus statement and was poorly answered. Candidates rarely gave a clear working description of a covalent bond, often overemphasising the importance of 'non-metal' whilst not demonstrating an understanding that this is a bond between two atoms. A covalent bond is the sharing of **two** electrons between **two** atoms.

The most common error made by candidates who understood covalent bonding was to use the phrase 'two or more shared pairs of electrons'. Only two electrons (one pair) are present in one covalent bond. Weaker responses tended to use the phrase 'between two or more atoms'; the electrons in a covalent bond cannot be shared by more than two atoms.

(b) (i) Many candidates referred to charges on chlorine or to the valency of chlorine and did not appreciate that the use of Roman numerals indicates a positive oxidation number only.

(ii) Most candidates completed the dot-and-cross diagram correctly.

(iii) This question proved difficult for nearly all candidates.

Good responses explained:
- For boiling, attraction between molecules needs to be broken.
- For decomposition, attraction between atoms needs to be broken.
- Attraction between molecules is weaker than attraction between atoms.

For boiling, many candidates used the phrase 'Cl_2O has weak intermolecular forces', but others showed a misunderstanding and wrote 'intermolecular forces between atoms', thus contradicting he term 'intermolecular'.

(iv) The most common error was for candidates to state that Cl_2O had no electrons. These candidates did not realise that there are many electrons in Cl_2O , but none of them are mobile. The terms 'free electrons' or 'delocalised electrons' are not equivalent phrases to 'mobile electrons'

Better performing candidates also stated that Cl_2O has no ions. The fact that the ions were not mobile was irrelevant.

(c) (i) Most candidates recognised graphite as the giant structure of carbon which conducts electricity.

(ii) Most candidates realised that electrons were the particles responsible for conduction of electricity.

(iii) Many candidates struggled to complete this diagram of the structure of SiO_2. Many did not read the question that silicon atoms had the symbol 'Si' and oxygen atoms had the symbol 'O'. Many diagrams featured symbols such as 'S', 'Si^{4+}', 'O^{2-}' and 'O_2'. The idea that Si would have four bonds and O would have two bonds was rarely known.

Question 3

(a) The definition of electrolysis was well known.

(b) (i) Most candidates stated the mass of the cathode remains the same rather than the correct increase in mass (due to deposition of Cu).

(ii) Very few candidates appreciated that Cu^{2+}(aq) ions would be deposited on the cathode, thus making the colour of the solution fade (until it eventually became colourless).

(iii) The description of effervescence was not seen very often.

(iv) This difficult ionic half-equation was known by many.

(c) (i) Most candidates stated the mass of the cathode remains constant rather than the correct increase in mass (due to deposition of Cu).

(ii) Many candidates appreciated that although Cu^{2+}(aq) ions would be deposited on the cathode, this would be equalled by Cu^{2+}(aq) ions dissolving from the anode thus maintaining the colour of the electrolyte.

(d) (i) Bauxite was known by nearly all candidates including many 'near-miss' spellings.

(ii) Cryolite was also known by most candidates.

(iii) Most candidates knew that carbon anodes reacted with the oxygen produced on them and the formation of carbon dioxide results in the need for continual replacement.

Question 4

(a) (i) Most candidates completed the equation correctly.

(ii) Very few candidates gave the expected response that the chromium produced would need separating from iron but gave equally creditworthy responses based upon the toxicity of CO.

(b) Alloy was almost universally known.

(c) (i) LO 6.4.9(d) of the syllabus states ‘the sum of the oxidation numbers in an ion is equal to the charge on the ion’. Many candidates were unaware of this.

(ii) Many realised that the sum of oxygen’s oxidation numbers was – 14 (or 7 × –2); frequently, the final answer was given as ‘6’ rather than ‘+6’.

(iii) Most candidates coped well with this calculation and candidates seemed well practiced in this type of calculation. The common error was to either multiply by 24 instead of 24 000 or to divide by either.

Question 5

(a) The group number of the alkali metals was almost universally known.

(b) Candidates performed well on **(i)** to **(iii)** which were based upon trends seen in Group I metals. Only a few candidates did not opt for either the top element or the bottom element of the group.

In **(iv)** and **(v)**, most candidates knew potassium burned with a lilac flame and was found in fertilisers.

(c) Most candidates were well practiced in drawing the electronic configuration of ions.

Very few candidates incorrectly showed electrons present in the third shell of Na and the same electrons being present in the third shell of S (usually accompanied by an arrow showing the transfer).

(d) (i) Isotope(s) was almost universally seen with only the occasional candidate opting for ‘isomer(s)’.

(ii) Most candidates coped well with this question about numbers of sub-atomic particles. Common errors included 38 electrons instead of 36 for the Rb^+ ion and using relative isotopic masses for the neutron number.

(iii) Most candidates found this very challenging and there was evidence of use of long and time-consuming algebraic methods as they attempted to rearrange the original formula for calculation of relative atomic mass. A few seemed to arrive at 75 by a simpler method.

Common errors seen were: (85.5 × 85)/100 = 72.7; 85; 85/85.5 × 100 = 99.4; 25 gained by incorrect use of the algebraic method; 85.5/85 × 100 = 100.6.

Question 6

(a) Most candidate gave the correct response of ‘homologous series’. Amongst weaker responses, common incorrect answers were: ‘isomers’, ‘homologous’ (alone) and ‘hydrocarbons’.

(b) Due to an issue with this question, full marks were awarded to all candidates to make sure that no candidates were disadvantaged. This question showed the term ‘relative atomic mass’ in place of ‘relative molecular mass’. The typographical error has been corrected in the published version of the paper.

(c) Most candidates performed well. Some did not balance the equation. Weaker responses did not understand the meaning of combustion, as equations lacking O_2 as a reactant were seen. The most common error was to give $CO_2 + H_2$ as the products.

(d) (i) Many candidates understood the effects of external factors on equilibria and most performed well here.

(ii) Many candidates were able to use collision theory to explain the changes in rate of reaction. Most stated the kinetic energy of the particles increased. A common error was stating 'kinetic energy increased' without relating this statement to 'particles'.

Most also stated there was an increased frequency of collisions. Relatively few candidates used the incorrect 'there are more collisions'.

Few clearly stated that a greater percentage of particles have energy greater than the activation energy and poor phrasing was common. The most common error was to state 'particles have energy greater than activation energy', which implies all particles have energy greater than activation energy.

(e) (i) Apart from the occasional miscounting of atoms the common error was to give a semi-structural formula.

(ii) The phrase 'there are double bonds present', as a description of unsaturation was not credited as this molecule clearly had C=O double bonds. Only the better performing candidates gave the fully correct statement that 'there was a carbon-carbon double bond present'.

(iii) This was a challenging question for many candidates who often did not remove the double bond from the monomer unit or attempted to form a chain of 4 carbon atoms. Some candidates showed two carbon atoms, each with 4 bonds, joined by a single bond and with continuation bonds but often had poor connectivity to the COOH groups.

(iv) This question proved very challenging for many candidates. Many answers just explained reacting ratios, repeated the question, stated that compound **B** was more concentrated / a strong acid or discussed the differences in M_r between the two reactants. Very few related the stoichiometry to the fact that compound **B** had two COOH groups.

(v) This difficult question was well answered by candidates who performed well overall. For other candidates, the 2 : 1 mole ratio was frequently overlooked and in the calculation of volume of NaOH(aq) containing the number of moles of NaOH calculated, many candidates did not convert $0.8\,dm^3$ to $800\,cm^3$.

CHEMISTRY

Paper 0971/51
Practical Test

Key messages

- The Confidential Instructions state that the supervisor must do the experiments in **Questions 1** and **2** and record the results on a copy of the question paper. These results must then be included with the scripts from the centre when they are returned. Where the practical exam has taken place in more than one practical session or laboratory, it should be clear which set of supervisor's results are for which session or laboratory and also which candidates were in which session or laboratory.

- Measurements taken from a given item of apparatus should all be recorded to the same resolution (the same number of decimal places).

- When plotting graphs, points should be plotted as a cross (x) or an encircled dot (⊙) and not obscured by the graph line, which should be drawn using a sharp pencil. A line of best fit can be curved or straight – whichever is the best fit for the data points. Straight lines should be drawn with the aid of a ruler and not drawn freehand, curves should be smooth and not just a line which moves from point to point. Graph scales should be chosen such that the plotted data takes up over half of the available space and it is recommended that each major grid line should be equivalent to 1, 2, or 5 (or those numbers multiplied by 10^n) – this is indicated in the Presentation of Data section of the syllabus in the section entitled 'Graphs' (and also recommended by the Association for Science Education (A.S.E.)).

- In the qualitative analysis question (**Question 2**) where a question states, 'Identify the gas given off', candidates are expected to record the details for the gas test that gives a positive result. Candidates are expected to use the term 'precipitate' when describing the formation of a solid from the reaction between two solutions; if when two solutions are mixed the product becomes cloudy and opaque then a precipitate has been formed. To state that a gas is given off is not an observation. The relevant observation would be effervescence or fizzing or bubbles (of a gas).

- In qualitative analysis, not all of the tests described will necessarily give a positive result; a negative test result is useful since it tells us that a certain ion is not in the compound being tested.

- When a question asks for the name of a chemical, a correct formula is always acceptable. However, if a candidate answers with an incorrect formula, then credit will not be awarded. When a question asks candidates to identify a substance, the name or formula is acceptable. However, incorrect names of formulas will not be accepted.

General comments

The vast majority of candidates successfully attempted all of the questions and the full range of marks was seen. The vast majority of candidates were able to complete all questions in the time available. The paper discriminated successfully between candidates of different abilities but was accessible to all. The paper was generally well answered, with very few blank spaces.

In answering the planning question (**Question 3**) there is no need for candidates to write a list of apparatus at the start, nor the aims of the experiment, nor a list of safety precautions or a list of dependent and independent variables. Where there is credit available for the use of suitable apparatus, then this will only be awarded if it is stated what the apparatus is used for; credit will not be awarded just for a name in a list of other apparatus.

Comments on specific questions

Question 1

(a) The majority of candidates were able to complete correctly Table 1.1 and record an increase in time from Experiment 1 to Experiment 5. The majority of candidates achieved a result for Experiment 1 that was comparable to the Supervisor's results. However, a significant number did not manage get a result of around half the time for Experiment 1 when compared to Experiment 3. The time would have been expected to be around half as it was twice the concentration. The most common error was not recording the time to a whole number as instructed for the experiments

(b) A number of fully correct graphs were seen. Common errors included:

- Inappropriate graph scales including non-linear scales. Candidates who chose awkward scales, such as each large grid square being equivalent 7, 8, 14 or 16 seconds often plotted points incorrectly and so did not gain credit for correctly plotting all five points. Points plotted in non-linear regions could not be awarded credit. Some candidates made the scale start from 0 on the *y*-axis when it was not appropriate which resulted in a non-linear scale. It was not required for the *y*-axis to start at 0 in this graph.
- By far the most common error was to draw a straight line of best fit through the points even when the points plotted lay on a curve. If the best-fit straight line has the points at either end of the line on one side and the points nearer the middle of the line on the other side, then that should suggest that the line should be a curve. Some candidates connected the points by a straight line when it was clear that the points lay on a curve. Some candidates drew graph lines in pen, this means that if an error is made the line cannot be erased and so multiple graph lines are seen.

(c) Most candidates indicated on the graph from where they were taking their reading and correctly recorded the expected time taken. The recommended method is to draw a vertical line from the required position on the *x*-axis (1.3 mol / dm^3) up to the graph line and then horizontally across to the *y*-axis in order to make the required reading. The majority of candidates read from their graph correctly at 1.3 mol / dm^3 and showed suitable working on their graph. Reading at 1.1 rather than 1.3 was not uncommon. Constructions on graphs should be drawn using a sharp pencil and be horizontal or vertical; some candidates gave incorrect readings because they drew construction lines that were at strange angles or were very wobbly, so they reached the *y*-axis in the wrong place. There were a significant minority of candidates who did not show any working. In these cases, credit was given for the reading if it was correct for 1.3 mol / dm^3.

(d) (i) Most candidates correctly calculated the numerical value of the rate using their value for time obtained in Experiment 1. Common errors included a rounding error or use of the value obtained from **(c)**. Answers left as fractions did not gain the credit available as fractions need to be evaluated. The units were more demanding, but many candidates gave them correctly as cm / s.

(ii) The vast majority of candidates identified Experiment 5 as the slowest.

(e) A very common error was for candidates to state that repeating an experiment makes it more reliable or more accurate – repeating makes no difference to reliability of accuracy. Another common error was to say repeating prevents anomalous results, in fact repeating increases the chance of an anomalous result. The advantage of repeating an experiment is that it enables results to be compared, this means anomalous results can be identified and excluded. Accuracy is improved by finding the average (mean) of the repeated results as this helps to remove random errors from the data.

(f) (i) Almost all candidates were able to record their temperatures and then calculate their temperature change. All values needed to be recorded correctly to a consistent number of decimal places. Almost all candidates gave a final temperature greater than the initial temperature that was comparable to the Supervisor results.

(ii) The investigation in **Question 1** was looking at how the rate of reaction of magnesium ribbon with dilute acid changes as the concentration of the acid changes. It is important to control the temperature of the acid in this reaction because an increased temperature will increase the rate of reaction and so the concentration is not the only independent variable.

(iii) The required answer was based on the fact that polystyrene would act as an insulator or reduce heat loss from the acid. This would actually increase the temperature change of the acid, as the reaction is exothermic and so have a greater effect on the rate of the reaction. A large number of candidates suggested that polystyrene is not an insulator.

(iv) Better performing candidates often gave a correct suggestion of using a water-bath. A water-bath will help control the temperature because heat will be lost more quickly to water than to air and so heat energy will be removed from the acid, helping to prevent the temperature increasing.

Question 2

(a) (i) Some candidates gave full and detailed observations. Almost all candidates stated they observed effervescence. If the candidate finds the word 'effervescence' hard to spell, fizzing or bubbling are appropriate alternatives. They do not have to write all three. To state that a gas is given off is not an observation. The relevant observation would be effervescence or fizzing or bubbles (of a gas). Very few candidates recorded an observation of the formation of a colourless solution or the solid dissolving/disappearing. Many candidates incorrectly recorded the formation of a precipitate. Presumably this was due to there being unreacted solid left over or forgetting to refer to the limewater gas test where a white precipitate would form and cause the limewater to appear cloudy. The correct positive gas test (limewater turning milky for carbon dioxide) was recorded by many candidates. A significant number of candidates recorded litmus turning red or lit splints being extinguished. These are not tests for the presence of carbon dioxide. A small number of candidates managed to record impossible results such as the bleaching of litmus paper or litmus turning blue. When recording a positive result for a gas test, candidates must state the test e.g. limewater turns milky/forms a white precipitate.

(ii) The majority of candidates were awarded credit for identifying carbon dioxide. A significant number managed to gain credit for this question but had not written down their gas test results in the previous question. Candidates often quoted the formation of a white precipitate without reference to limewater. Those who recorded impossible gas test results almost invariably stated the wrong gas.

(b) (i) This question was well answered by many candidates, however, a significant number managed to get white precipitate or even fizzing. This was a test for the presence of sulfate ions. Solution **H** was calcium chloride so no sulfate or carbonate ions were present. No precipitate would have formed and no fizzing would have been observed. The correct response was no change. Colourless solution was accepted, however, formed/becomes a colourless solution was rejected as it implies a change had occurred

(ii) This question was often well answered for the dropwise addition of the sodium hydroxide and many candidates stated correctly that a white precipitate had formed. It was common to see vague descriptions of a precipitation reaction occurring such as a 'solid formed' or 'it turns cloudy'. To gain credit, candidates must refer to the formation of a precipitate. For addition of the sodium hydroxide in excess, candidates often incorrectly stated that the precipitate dissolves or a solution formed. The product of this reaction would be calcium hydroxide and is insoluble in excess. Details can be found in the notes for use in qualitative analysis at the back of the paper. Some responses stated the incorrect colour of precipitates.

(iii) This was a precipitation reaction where calcium carbonate would be formed as a precipitate. To gain credit, reference to both the formation of a precipitate and the colour (white) was required. A notable number of candidates recorded no change or colourless solution as their result.

(c) This was well answered by many candidates. Candidates needed to identify both ions to gain full credit. The majority of candidates managed to identify calcium ions, but a large number could not identify the anion correctly. Common incorrect ions were aluminium in place of calcium and sulfate in place of carbonate. Some candidates tried to identify solution **H** rather than solid **F**. Both the name and formula were accepted, however, if a formula is given then it must be correct.

(d) Many candidates observed a lilac colour and were awarded credit. Credit was given for other colours only given if the colour given matched the centre Supervisor result. If the centre does not record a result, no credit can be given for the observation if it not the expected observation for the ion present.

(e) (i) This was a more demanding observation. This was the test for the presence of halides. Most candidates managed to record that a precipitate had formed, however, most stated that a white precipitate had formed. The compound was lithium bromide and bromide will form a cream precipitate. Yellow precipitate was seen occasionally and other colours such as red, blue and green were given.

(ii) This question was well answered, and the majority of candidates were awarded the credit available. A significant minority of candidates recorded the formation of a yellow precipitate rather than a yellow/orange/brown solution or referred to the colour green e.g. yellow-green. The formation of a precipitate was rejected as was the colour green. This is a displacement reaction where chlorine displaces bromine. No precipitate will form.

(f) This was well answered by lots of candidates. Chloride was a very common response. Iodide was rarely seen. On occasion, some candidates listed more than two ions. Any incorrect ion was rejected.

Question 3

This planning task was a quantitative task and so candidates were expected to make measurements as part of the plan. Those measurements should have included the quantities of each reagent and the temperature before and after the reaction.

There was clearly some confusion with the meaning of the term endothermic. An endothermic reaction is one in which heat energy (from the surroundings) is converted to chemical potential energy in the substances reacting. A decrease in heat energy means a decrease in temperature. It is not helpful to think of the surroundings as the room in which the reaction is done, the surroundings for this reaction is the solvent in which the reaction occurs (the water in the dilute hydrochloric acid) – that is, the contents of the container in which the reaction is done. While the temperature of the room may drop by a small fraction of a degree (far too small to measure on a standard laboratory thermometer), the temperature of the reaction mixture will change by several degrees Celsius.

The expected steps for the plan were:
- use a known or stated volume of dilute hydrochloric acid
- measure the initial temperature of the acid
- use appropriate apparatus, such as a measuring cylinder, to measure the volume of the acid and place the acid in a suitable reaction vessel such as a conical flask
- add a known mass of solid sodium hydrogencarbonate to the acid
- stir the acid and sodium hydrogencarbonate to mix them
- measure the final temperature of the acid
- state that the reaction with the largest decrease in temperature is the most endothermic.

While many excellent and often concise plans were seen, there were a number of common errors including:
- not controlling the volume of acid or mass of sodium hydrogencarbonate
- not identifying appropriate apparatus
- trying to measure the temperature of the solid sodium hydrogencarbonate rather than the acid
- not mixing the reagents together
- writing about temperature increases
- using a water-bath. A water-bath will minimise the change in temperature and so defeat the aim of the investigation.

Some candidates heated the reaction mixture in some way; this will mean that any recorded temperature change is not due to the endothermic nature of the reaction.

Some answers, rather than being based on temperature change, focused on rate of reaction, volume of gas made or mass change and tried to make an incorrect link between these things and the endothermic nature of the reaction.

CHEMISTRY

Paper 0971/61
Alternative to Practical

Key messages

- When plotting graphs, points should be plotted as a cross (x) or an encircled dot (⊙) and **not** just a small dot which is obscured by the graph line, which should be drawn using a sharp pencil. A line of best fit can be curved or straight – whichever is the best fit for the data points. Straight lines should be drawn with the aid of a ruler and not drawn freehand, curves should be smooth and not just a line which moves from point to point. A best fit line should have an approximately equal number of points on each side of the line (excluding anomalous results). Candidates will need to decide if the line should be curved or straight. If a straight line has the points at either end of the line on one side of the line and the points in the middle on the other side, then the best fit line is likely be a curve. Graph scales should be chosen such that the plotted data takes up over half of the available space and it is recommended that each major grid line should be equivalent to 1, 2, or 5 (or those numbers multiplied by 10^n) – this is indicated in the Presentation of Data section of the syllabus in the section entitled 'Graphs' (and also recommended by the Association for Science Education (A.S.E.)).

- Readings recorded from a given item of apparatus should all be recorded to the same resolution (the same number of decimal places).

- In the qualitative analysis question (**Question 3**), where a question states that any gas produced is tested, candidates are expected to record the details for the gas test that gives a positive result. Candidates are expected to use the term 'precipitate' when describing the formation of a solid from the reaction between two solutions. If when two solutions are mixed the product becomes cloudy and opaque then a precipitate has been formed. To state that a gas is given off is not an observation. The relevant observation would be effervescence or fizzing or bubbles (of a gas).

- When a question asks for the name of a chemical, a correct formula is normally acceptable. However, if a candidate answers with an incorrect formula, then credit will not be awarded. When a question asks candidates to identify ions or a substance then candidates may answer using names of formulae.

- In qualitative analysis, not all of the tests described will necessarily give a positive result; a negative test result is useful since it tells us that a certain ion is **not** in the compound being tested.

General comments

The vast majority of candidates successfully attempted all of the questions and the full range of marks was seen. The vast majority of candidates were able to complete all questions in the time available. The paper discriminated successfully between candidates of different abilities but was accessible to all. The paper was generally well answered, with very few blank spaces.

Some candidates omit questions when the answer needs to be written on a diagram and there is no dotted answer line. These errors of omission would not occur if candidates read the whole of each question on the examination paper rather than just looking for dotted lines on which other answers should be written.

In answering the planning question (**Question 4**), there is no need for candidates to write a list of apparatus at the start, or the aims of the experiment, or a list of safety precautions or a list of dependent and independent variables. Where there is credit available for the use of suitable apparatus, then this will only be awarded if it is stated what the apparatus is used for. Credit will not be awarded just for a name in a list of other apparatus.

Comments on specific questions

Question 1

(a) The majority of the candidates calculated correctly the volume of dilute sulfuric acid added. A small number of candidates added the final and initial burette readings rather than subtracting initial from final. Some candidates did not attempt this question.

(b) Candidates had to correctly identify the least concentrated solution (aqueous potassium carbonate) and give a correct reason for their answer. The required reason was that the volume of aqueous potassium carbonate used was greater than the volume of dilute sulfuric acid. It was common for candidates to identify sulfuric acid as the least concentrated and then, as the reason, state the expected reason that shows aqueous potassium carbonate is the least concentrated. Some candidates did not use the data in Table 1.1 and stem of the question, instead saying that the aqueous potassium carbonate is least concentrated because it contains water or that the sulfuric acid is the least concentrated because it is dilute.

(c) Almost all candidates could name an item of apparatus suitable for measuring 25.0 cm^3 of aqueous potassium carbonate.

(d) Most candidates were able to name a suitable acid-alkali indicator to use; the most popular choice being methyl orange. Those who chose thymolphthalein or phenolphthalein often had difficulty spelling the name. Credit was awarded if the indicator could be recognised; however, some attempts at spelling were such that the indicator could not be identified. It should be noted that universal indicator is not suitable for use in a titration as it does not have a sharp end point. The colour change at the end point depended on the indicator chosen; if no indicator was chosen, or the indicator was not an acid-alkali indicator, then credit could not be awarded for the colour change. For methyl orange, that change should have been from yellow (the colour in an alkaline solution) to orange (the colour that is a mix of the colour in alkaline solution and the colour in acidic solution (red). A change of yellow to red was allowed, but changing to red means the end-point has been overshot. It was a common error to give the colour change for the indicator chosen the wrong way round (so from acid to alkali).

(e) The vast majority of candidates correctly stated that the contents of the flask should be mixed in some way. The most common answers were use of a white tile or adding slowly; while these are things that are relevant to a titration, they are not things the candidate does while adding the acid.

(f) Candidates are expected to be familiar with methods of salt preparation, including the preparation of a soluble salt by a titration-based method. They should also be familiar with the process of crystallisation.

As a pure sample of potassium sulfate was required, the first stage should have been to mix together the volumes of aqueous potassium carbonate and dilute sulfuric acid that have been found to produce a neutral solution. This was rarely awarded. Many candidates described that once the solution has been obtained, it needs to be heated to the point of crystallisation and then the hot saturated solution cooled so that crystals form. A common error was to think that potassium sulfate was insoluble and so could be filtered out from the titration mixture and the residue washed; the equation for the reaction showed that the potassium sulfate made was aqueous.

Question 2

(a) The majority of candidates completed Table 2.1 correctly. The most common errors were not reading the stop-watch diagrams correctly; the time in Experiment 4 was often given as 51 rather than 56 s. The instructions for Experiment 1 stated '...and record the time in seconds to the nearest second', this means that times shown to a greater precision than the nearest second did not gain full credit (so times such as 42.0 rather than 42 were not accepted) and neither were times shown in minutes and seconds. Some candidates ignored the minute hand and so gave the time for Experiment 5 as 35 seconds.

(b) Most candidates produced a sensible graph scale, the most common being the expected scale where each large grid square was 20 seconds. Those who chose difficult scales (such as each large square being 15, 19 or 24 seconds, all of which were seen) often made errors in the plotting and so did not gain the two marks available for the correct plotting of all five points. The best-fit line for the correctly plotted points was a curve. Many candidates drew straight lines, often just from first point to last, these lines did not gain credit for drawing an appropriate line of best fit. Many lines had the points at either end of the line on one side of the line and the points in the middle on the other side; this should have suggested to candidates that the points may lie on a curve. Some candidates are still drawing graph lines in pen; this means that if an error is made, the line cannot be erased and so multiple graph lines are seen.

(c) The majority of candidates correctly read from their graph at 1.3 mol/dm^3 and showed suitable working on their graph. Reading at 1.1 rather than 1.3 was not uncommon. Constructions on graphs should be drawn using a sharp pencil and be horizontal and vertical; some candidates gave incorrect readings because they drew construction lines that were at strange angles or were very wobbly, so they reached the *y*-axis in the wrong place.

(d) (i) Most candidates correctly calculated the numerical value of the rate as 0.25, although some answers were an order of magnitude out or the candidate inverted the calculation and gave an answer of 4. Answers left as fractions did not gain credit, as fractions need to be evaluated. The units were more demanding, but many candidates gave them correctly as cm / s.

(ii) The vast majority of candidates identified Experiment 5 as being the slowest.

(e) A very common error was for candidates to state that repeating an experiment makes it more reliable or more accurate – repeating makes no difference to reliability or accuracy. Another common error was to say repeating prevents anomalous results. The advantage of repeating an experiment is that it enables results to be compared; this means anomalous results can be identified and excluded. Accuracy is improved by finding the average (mean) of the repeated results as this helps to remove random errors from the data.

(f) (i) Most candidates were able to read the thermometer diagrams correctly. Credit was also available for giving **all** values to the nearest 0.5 and correctly subtracting the temperature readings to give a change of 22.5. The most common error was to record the first thermometer reading as 24 rather than 24.0.

(ii) The investigation in **Question 2** was looking at how the rate of reaction of magnesium ribbon with dilute acid changes as the concentration of the acid changes. It is important to control the temperature of the acid in this reaction because an increased temperature will increase the rate of reaction and so the concentration is not the only independent variable.

(iii) The required answer was based on polystyrene acting as an insulator or reducing heat loss from the acid. This would actually increase the temperature change of the acid, as the reaction is exothermic, and so have a greater effect on the rate of the reaction. A large number of candidates suggested that polystyrene is not an insulator.

(iv) Better performing candidates often gave a correct suggestion of using a water bath. A water bath will help control the temperature because heat will be lost more quickly to water than to air and so heat energy will be removed from the acid, helping to prevent the temperature increasing.

Question 3

(a) As the question stated that any gas produced was tested, candidates were expected to give the test and positive result for the gas produced. As a total of two marks were available, the second mark was for an observation that would be made during the reaction. As one of the products of the reaction is carbon dioxide, there should be effervescence (or bubbles/fizzing); the positive test for carbon dioxide is that it should turn limewater milky. Additional incorrect positive gas tests or observations contradict a correct observation or gas test.

(b) (i) The filtrate, solution **H**, was aqueous calcium chloride. The test carried out was the test for sulfate ions. As there are no sulfate ions in aqueous calcium chloride, there should have been no change. A common error was to state 'white precipitate'; the expected result for a positive sulfate test.

(ii) The expected observations on addition of aqueous sodium hydroxide was the formation of a white precipitate on dropwise addition, which then remained when excess aqueous sodium hydroxide was added. The vast majority of candidates performed well, however, some candidates gave the expected result for the addition of aqueous ammonia or thought that ammonia would be made (possibly confusing the test used with the test for ammonium ions).

(iii) As solution **H** was aqueous calcium chloride, the expected result was the formation of a white precipitate. Many candidates said there would be no change, presumably because solid **F** was calcium carbonate and so did not contain a halide ion. An unexpectedly common incorrect answer was the formation of a yellow precipitate; this would require the presence of iodide ions, which are not mentioned anywhere in **Question 3** or elsewhere on the examination paper.

(c) Many candidates correctly identified solid **G** as potassium bromide. It was not uncommon for candidates to identify just one of the ions, normally the potassium ion from the flame test colour.

Question 4

This planning task was a quantitative task and so candidates were expected to make measurements as part of the plan. Those measurements should have included the quantities of each reagent and the temperature before and after the reaction.

There was some confusion with the meaning of the term endothermic. An endothermic reaction is one in which heat energy (from the surroundings) is converted to chemical potential energy in the substances reacting. A decrease in heat energy means a decrease in temperature. It is not helpful to think of the surroundings as the room in which the reaction is done, the surroundings for this reaction is the solvent in which the reaction occurs (the water in the dilute hydrochloric acid) – that is, the contents of the container in which the reaction is done. While the temperature of the room may drop by a small fraction of a degree (far too small to measure on a standard laboratory thermometer), the temperature of the reaction mixture will change by several degrees Celsius.

The expected steps for the plan were:
- use a known or stated volume of dilute hydrochloric acid
- measure the initial temperature of the acid
- use appropriate apparatus, such as a measuring cylinder, to measure the volume of the acid and place the acid in a suitable reaction vessel such as a conical flask
- add a known mass of solid sodium hydrogencarbonate to the acid
- stir the acid and sodium hydrogencarbonate to mix them
- measure the final temperature of the acid
- state that the reaction with the largest decrease in temperature is the most endothermic.

While many excellent and often concise plans were seen, there were a number of common errors:
- not controlling the volume of acid or mass of sodium hydrogencarbonate
- not identifying appropriate apparatus
- trying to measure the temperature of the solid sodium hydrogencarbonate rather than the acid
- not mixing the reagents together
- writing about temperature increases
- using a water-bath. A water-bath will minimise the change in temperature and so defeat the aim of the investigation
- heating the reaction mixture. If this is done, there will be no way of finding out the temperature change caused by the reaction.

Some candidates heated the reaction mixture in some way; this will mean that any recorded temperature change is not due to the endothermic nature of the reaction.

Some answers, rather than being based on temperature change, focussed on rate of reaction, volume of gas made or mass change and tried to make an incorrect link between these things and the endothermic nature of the reaction.

CHEMISTRY

Paper 0971/62
Alternative to Practical

Key messages

- When plotting graphs, points should be plotted as a cross (x) or an encircled dot (⊙) and **not** just a small dot which is obscured by the graph line, which should be drawn using a sharp pencil. A line of best fit can be curved or straight – whichever is the best fit for the data points. Straight lines should be drawn with the aid of a ruler and not drawn freehand, curves should be smooth and not just a line which moves from point to point. A best fit line should have an approximately equal number of points on each side of the line (excluding anomalous results). Candidates will need to decide if the line should be curved or straight; if a straight line has the points at either end of the line on one side of the line and the points in the middle on the other side, then the best-fit line should probably be a curve. Graph scales should be chosen such that the plotted data takes up over half of the available space and it is recommended that each major grid line should be equivalent to 1, 2, or 5 (or those numbers multiplied by 10^n) – this is indicated in the Presentation of Data section of the syllabus in the section entitled 'Graphs' (and also recommended by the Association for Science Education (A.S.E.)).
- Readings recorded from a given item of apparatus should all be recorded to the same resolution (the same number of decimal places).
- In the qualitative analysis question (**Question 3**), where a question states that any gas produced is tested then candidates are expected to record the details for the gas test that gives a positive result. Candidates are expected to use the term 'precipitate' when describing the formation of a solid from the reaction between two solutions; if when two solutions are mixed the product becomes cloudy and opaque then a precipitate has been formed. To state that a gas is given off is not an observation. The relevant observation would be effervescence or fizzing or bubbles (of a gas).
- When a question asks for the name of a chemical, a correct formula is normally acceptable. However, if a candidate answers with an incorrect formula, then credit will not be awarded. When a question asks candidates to identify ions or a substance then candidates may answer using names of formulae.
- In qualitative analysis, not all of the tests described will necessarily give a positive result; a negative test result is useful since it tells us that a certain ion is **not** in the compound being tested.

General comments

The vast majority of candidates successfully attempted all of the questions and the full range of marks was seen. The vast majority of candidates were able to complete all questions in the time available. The paper discriminated successfully between candidates of different abilities but was accessible to all. The paper was generally well answered, with very few blank spaces.

Some candidates omitted **Question 1(d)** where the answer needed to be written on a diagram and there is no dotted answer line. These errors of omission would not occur if candidates read the whole of the questions on the examination paper rather than just looking for dotted lines on which answers should be written.

In answering the planning question (**Question 4**), there is no need for candidates to write a list of apparatus at the start, nor the aims of the experiment, nor a list of safety precautions or a list of dependent and independent variables. Where there is credit available for the use of suitable apparatus, then this will only be awarded if it is stated what the apparatus is used for. Credit will not be awarded just for a name in a list of other apparatus.

Comments on specific questions

Question 1

(a) The majority of the candidates correctly named the gas syringe in Fig. 1.1. Syringe alone was an acceptable answer. The few incorrect answers included measuring cylinder and ruler.

(b) This proved to be a much more challenging question, with few using sandpaper to remove the oxide layer from the magnesium ribbon. The use of an acid was also acceptable, but most candidates incorrectly thought that washing with distilled water would be enough.

(c) Most realised that the mineral wool was there to hold or absorb the water, preventing it from flowing along the tube to where the magnesium ribbon was being heated.

(d) Most candidates were able to draw two arrows to show where heat was needed, under the mineral wool and under the magnesium ribbon. A significant number drew no arrows, presumably because there was no dotted answer line and they did not see or read the question. A few drew arrows to the rubber tubing.

(e) A large number correctly identified the liquid at **X** as water.

(f) Fewer than half correctly realised that there is air in the apparatus at the beginning of the experiment. Some candidates mentioned steam, although this would have condensed.

Question 2

(a) Almost all candidates successfully completed the table of results. It was expected that all temperatures and temperature changes would be recorded to the same resolution, in other words to the nearest half division on the thermometer, to the nearest 0.5 °C. This meant, for example, that 27.0 was expected, but 27 was insufficient.

(b) Most candidates produced sensible graph scales, the most common being each large grid square being either 2 or 2.5 °C . Those who chose difficult scales often made errors in the plotting and so did not gain the credit available for the correct plotting of all five points. The best-fit line was a smooth curve based on the data given in the question. Many candidates incorrectly drew straight lines, often just from the first point to last, when the points were clearly on a curve of decreasing gradient. Straight lines which have the points at either end of the line on one side of the line and the points in the middle on the other side suggests that the points lie on a curve. Some candidates drew their graph line in pen, this means that if an error is made the line cannot be erased and so multiple graph lines are seen. A few candidates use non-linear scales which makes it impossible to award credit for the scale and plotting.

(c) Most candidates were able to continue their graph line to the right so that a reading could be made at 45 cm^3. A significant number of candidates did not include the unit (°C) in their answer; all physical quantities should be accompanied by a unit.

(d) The calculation of the energy given out was completed successfully by the majority of candidates. A few incorrectly rounded 850.5 to 850.

(e) Most candidates realised that the increased mass of anhydrous lithium chloride would result in an increased temperature change. However, to gain full credit candidates were required to give a quantitative answer. Two different quantitative answer were accepted:

- The temperature change would be double the temperature change of Experiment 1 because the mass of anhydrous lithium chloride had doubled.
- The temperature change would be the same as Experiment 4 because the ratio of anhydrous lithium chloride : water was the same as in Experiment 4.

Some candidates incorrectly based their explanation on more anhydrous lithium chloride requiring more energy to dissolve. As the process is exothermic, energy is released and not taken in.

(f) The required answer was based on the fact that polystyrene would act as an insulator and so reduce heat loss from the solution. Less heat energy lost would mean a larger temperature rise. A significant number of candidates based their answer on the polystyrene cup being a more accurate method of measuring a volume than a beaker.

(g) (i) The vast majority of candidates correctly stated that a burette measures volumes more accurately than a measuring cylinder.

(ii) This proved to be a demanding question. In the experiments, heat energy is given out and results in the temperature of the solution increasing. Heat energy lost from the system (the beaker) results in a smaller temperature increase. If the beaker is stood in a water-bath then more heat energy will be transferred from the beaker to the water-bath and so the temperature change will be even smaller, or possibly so small as to be not measurable with the apparatus provided. Water-baths maintain a constant temperature and so are not suitable when the dependent variable (the required outcome of the investigation) is the temperature change.

Question 3

Candidates were told that solid **J** was iron(II) iodide

(a) Most candidates correctly gave the formation of a green precipitate on the dropwise addition of aqueous sodium hydroxide. The precipitate should have remained when excess aqueous sodium hydroxide was added, although a number of candidates stated that the precipitate then dissolved, which is the result if it had been a chromium(III) compound.

(b) This was the test for sulfate ions. As there are no sulfate ions in solid **J**, there should have been no change. A common error was to state 'white precipitate', the expected result for a positive sulfate test.

(c) This was the test for halide ions. As solid **J** contained iodide ions, a yellow precipitate was expected. Although some candidates stated that there was no change, most noted the formation of a precipitate.

(d) Addition of aqueous chlorine will result in the oxidation of iodide ions to iodine. This would have resulted in aqueous iodine, giving the solution a yellow, orange or brown colour.

(e) Candidates were told that, in test two, the test for ammonium ions, red litmus remained red. Whilst many correctly stated that solid **K** was not an ammonium salt, a common incorrect answer was to say that an acid was made or that solid **K** was acidic. Red litmus not changing colour does not show an acid has been made, red litmus can detect alkalis but not acids, blue litmus can detect acids but not alkalis.

(f) Most candidates correctly identified the gas in **test 3** as ammonia.

(g) Many candidates correctly identified solid **K** as potassium nitrate. It was not uncommon for candidates to identify just one of the ions, normally the potassium ion from the flame test colour.

Question 4

This planning task was a quantitative task, and so candidates were expected to make measurements as part of the plan.

The most common appropriate methods seen involved:

- Using apparatus, such as a measuring cylinder, to put a stated volume of water in a suitable container such as a beaker or conical flask.
- Warming the water to a temperature of 50 °C.
- Describing some method of keeping the water at the required temperature, such as a water bath or insulated container.
- Adding an excess of magnesium sulfate.
- Stirring to speed up dissolving.
- Filtering to remove the excess magnesium sulfate.

Then finding the mass of magnesium dissolved by either:

- weighing the filtrate and subtracting from that the mass of the water used or
- drying the residue and subtracting the mass of the residue from original mass of the magnesium sulfate or
- evaporating the filtrate to dryness and finding the mass of the solid left.

In all three cases, the mass found is the mass of magnesium sulfate dissolved in the volume of water used.

Many excellent fully correct answers were seen. Some common errors included:

- Not identifying the apparatus used. Credit will not be given for a list of apparatus at the start of the plan; candidates need to state what the apparatus is used for.
- Not stirring the mixture to help dissolve the magnesium sulfate. Relying just on diffusion means the experiment will take many hours.
- At the end, either not drying the residue from filtration or not evaporating to dryness the filtrate. Leaving the residue wet or just heating the filtrate to crystallising point will not give a correct answer.
- Washing the residue obtained after filtration – this will cause more of it to dissolve and so any masses obtained will be incorrect.
- Doing an extra step in the calculation of dividing the final answer by 100. If the volume of water used is 100 cm^3 then the mass obtained is the solubility in g per 100 cm^3 of water.