# CHEMISTRY

**Paper 0971/12**
**Paper 1 Multiple Choice (Core)**

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

# CHEMISTRY

**Paper 0620/22**
**Paper 2 Multiple Choice (Extended)**

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

## General comments

Overall, candidates found this to be an accessible paper. **Questions 3**, **7**, **27** and **28** had the lowest demand and **Questions 12**, **13**, **16**, **19** and **32** had the highest demand. There was a good distribution of marks with some candidates doing particularly well. Organic chemistry, in particular the structures of molecules, was a strong discriminator between candidates.

## Comments on specific questions

**Question 5**

This question discriminated well between candidates with some candidates more likely to choose any of the incorrect options. Option **A** was most commonly chosen, showing some confusion about bonding in compounds of the Group **I** elements.

**Question 8**

Candidates who performed less well overall appeared to be guessing. A significant number of candidates chose option **D** which suggests some confusion about the meaning of the term ‘empirical formula’.

**Question 10**

The products of the electrolysis of molten and aqueous salts were confused by many of the candidates who performed less well overall. Option **B** was a common incorrect answer.

**Question 12**

This question was not well answered, and the distribution suggests some candidates were guessing. The most common incorrect answer was option **C** where candidates confused the terms endothermic and exothermic.

**Question 13**

Perhaps due to confusion between the terms endothermic and exothermic, this question was poorly answered. The combustion reaction shown in option B was the most commonly chosen answer.

**Question 16**

A small majority of candidates identified the correct direction of movement for the position of equilibrium but confused the effect of temperature on the rates of both the forward and backward reactions. Option **C** was chosen by more than a third of the candidates.

**Question 19**

Candidates were more likely to choose any of the other options than the correct answer. Option **B** was a popular answer. Although the precipitation reaction is correctly described, it is not correct to describe it as an acid-base reaction.

**Question 21**

Some candidates appeared to have been guessing.

**Question 32**

Most candidates identified the reaction in a catalytic converter, but many candidates were confused as to the source of the nitrogen and oxygen which form the oxides of nitrogen. Option **C** was the most common answer.

**Question 33**

This question discriminated well between candidates. Option **B** was chosen by a third of the weaker candidates. This shows recognition of the carbon–carbon double bond in an alkene but not that carbon can only form four bonds.

**Question 37**

Some candidates thought that nylon is a polyester rather than a polyamide and chose option **D**. A significant number also confused condensation and addition polymerisation and chose option **A**.

**Question 38**

Few candidates chose options **A** or **D**. Candidates who performed less well overall were more likely to choose option **B**, which shows carbon making more than four bonds.

# CHEMISTRY

**Paper 0971/32**
**Paper 3 Theory (Core)**

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

# CHEMISTRY

**Paper 0971/42**
**Paper 4 Theory (Extended)**

## Key messages

- Candidates should not use charges with formulae in chemical equations and should take care over the use of capital or lower-case letters and use of subscript. The following were all examples of the formula of lead(II) chloride, $PbCl_2$, which did not receive credit: $Pb^{2+}Cl_2$, PbC$l$ 2, $PBCl_2$, $pbCl_2$.

- Candidates should not provide fractions as answers to calculations.

- If one answer is required, candidates should refrain from giving more than one response.

## General comments

There appeared to be sufficient time for all questions to be answered.

Some candidates overwrote changes to their responses which can make them difficult to credit, particularly if they are similar letters or numbers. To cross out and replace would ensure candidate's work is visible.

Many definitions and terms introduced into the new 2023 syllabus were not known.

## Comments on specific questions

### Question 1

Candidates performed well, apart from **(g)** where only about a quarter of the candidates knew that electronic configuration **B** (2,8) was that of an **ion** of a Group V element. Most selected **A** (2,5) or **E** (2,8,5), which were both electronic configurations of Group V **atoms**.

Only the letters representing electronic configurations were required, however, a significant number unnecessarily tried to repeat the electronic configuration or attempted to name the species.

### Question 2

**(a) (i)** Candidates performed well on this question – the most common error being to give the $Cu^{2+}$ ion two more electrons than the number of protons.

**(ii)** Most candidates multiplied each isotopic mass by the relative abundance, added these values then divided by the total relative abundance.

Some went on to give the answer as a whole number value rather than an answer to one decimal place as asked in the question.

**(b)** Most candidates gave the expected responses of melting point and density. Some candidates stated 'hardness' but this was given in the question so received no credit. By far the most common error was to give differences in **chemical** properties such as: catalytic activity, formation of coloured compounds and, occasionally, variable oxidation number.

**(c) (i)** Although the concept was understood, the syllabus definition of water of crystallisation was not known. Common answers that were insufficient included ‘water inside crystals’ or ‘water needed to make crystals’.

**(ii)** The pink colour of hydrated cobalt(II) chloride was quite well known. Higher performing candidates gave the correct formula, $CoCl_2.6H_2O$. Candidates who performed less well omitted waters of crystallisation completely or wrote $CoCl_2.5H_2O$, presumably because of confusion with $CuSO_4.5H_2O$.

**(iii)** The colour change when water is added to anhydrous copper(II) sulfate was well known.

**(iv)** Most knew that water was needed to be removed from hydrated copper(II) sulfate but many did not state that heating was needed to accomplish this. Vague responses such as, ‘remove the water’ or ‘evaporate the water’ achieved no credit.

**Question 3**

**(a)** Only the better performing candidates wrote ‘hot air’. Other candidates thought that carbon (or even carbon dioxide) was the other starting material. One common incorrect response was ‘oxygen’. Although oxygen is part of air, it is air that is the starting material.

**(b) (i)** ‘Hematite’ was known by many candidates as the main ore which contains $Fe_2O_3$. ‘Bauxite’ was the common error seen from some candidates.

**(ii)** Most candidates balanced the equation successfully.

**(iii)** Many candidates did not realise that, unless zero, oxidation numbers need a ‘+’ (or ‘–’, if applicable) before the integer. So ‘3’ for the oxidation number of Fe in $Fe_2O_3$ received no credit. The expected answer was +3. Candidates who performed less well gave incorrect responses, such as $Fe^{3+}$ and Fe(III).

**(iv)** The reduction of iron in terms of change in oxidation number being a decrease in this reaction was poorly answered. Many candidates simply relied upon the acronym ‘OILRIG’ and stated ‘iron lost electrons’. Others looked at the equation and stated that ‘iron lost oxygen’.

**(c)** Only the better performing candidates knew the relevant equations.

Equation 1, $CaCO_3 \rightarrow CaO + CO_2$, was better known than equation 2, $CaO + SiO_2 \rightarrow CaSiO_3$.

The reaction type for equation 1, thermal decomposition, was better known than that of equation 2 which needed candidates to realise it involved a metal oxide reacting with a non-metal oxide, so was an acid-base reaction. Most gave the acceptable alternative of ‘neutralisation’.

**(d) (i)** The correct term, ‘alloy’, was well known, although many thought the term was ‘compound’.

**(ii)** Some candidates were aware that the syllabus describes stainless steel as a mixture of iron and other elements such as chromium, nickel, and carbon, so the one element other than carbon in the making of stainless steel was likely to be chromium or nickel.

**(e)** Very few gave the answer ‘hydrated iron(III) oxide’.

**(f) (i)** Relatively few knew that coating steel with zinc is ‘galvanising’.

**(ii)** Most opted for ‘painting’ or ‘oiling’ as another barrier method.

**(iii)** Although better performing candidates answered correctly based upon zinc’s higher reactivity than iron and therefore reacting in preference to iron, many others assumed zinc acted as a barrier throughout the process.

**Question 4**

**(a) (i)** Better performing candidates gained full credit but many other candidates were not able to identify the two soluble salts based on the general solubility rules for salts in the syllabus.

To make lead(II) chloride, the soluble lead salt should have been lead(II) nitrate and the soluble chloride should have been, for instance, sodium chloride.

**(ii)** Some candidates struggle with ionic equations for precipitate formation. Such equations will always have two reactant *ions* and one product compound. In this question, the formula of the product compound, $PbCl_2$, was given. The sequence of state symbols will always be (aq) + (aq) → (s).

Errors were to only have one $Cl^-$(aq) ion as a reactant ion and other candidates attempted to write the complete symbol equation, usually unsuccessfully.

Candidates should be advised to identify the solid product and 'split' this up into its constituent ions. These will be the reactants.

**(iii)** Better performing candidates gave the three key points needed in the preparation of an insoluble salt from a reaction mixture: filtration; rinsing; drying. Many other candidates were confused by the practical nature of what was required.

Some candidates suggested heating the mixture, which contained a precipitate, to the crystallisation point and gained no credit. Others described how to prepare crystals from the filtrate and suggested filtration but went on to heat (presumably the filtrate) to the crystallisation point.

Many candidates are unsure of the meaning of residue and filtrate. Often responses would state, after filtration, 'rinse the filtrate then dry the filtrate'.

**(b) (i)** Better performing candidates knew that lead(II) chloride needed to be molten so ions would become mobile. Most candidates incorrectly stated it was electrons that needed to become mobile.

**(ii)** Candidates need to learn that during electrolysis negative ions are attracted to the anode and upon reaching the anode, they lose electrons. This would have helped them to write the ionic half-equation.

**(iii)** The test for chlorine gas was not very well known. Random gas tests were given e.g., 'glowing splint' and 'relights a splint'. Another common error was to add silver nitrate – an obvious confusion with the chloride ion test.

**(iv)** Candidates struggled to understand that 'Describe what is observed…' essentially means 'What would you see...'. Descriptions such as these need a colour (in this case grey) and a state. Thus, answers such as 'lead forms' did not receive credit, neither did 'solid forms' nor 'lead is deposited'.

**Question 5**

**(a)** Enthalpy change was not known by most candidates.

**(b) (i)** Candidates were not able to explain answers in terms of collision theory with great success. Many candidates omitted that rate of reaction increases.

Very few related the increase in rate of reaction to more particles per unit volume. A significant number correctly stated that the *frequency* of collisions (not just 'more collisions') of particles increases, but many of these candidates went on to incorrectly state that at higher concentrations the energy of the particles increased, or the activation energy changed.

**(ii)** Although some well-expressed answers were seen, many other candidates did not address the key focus of the question about *equilibrium*. Candidates need to be taught that it is the *equilibrium* which shifts and **not** the reaction. The reason for the shift in equilibrium should then be given. Many candidates struggled with their words and gave very unclear answers. There was some confusion between left and right with some candidates, as well as contradictory statements such as 'the equilibrium shifts towards the reactants' followed later by 'the equilibrium shifts to the right-hand side'.

Many irrelevant comments about rate of reaction change were also seen.

**(iii)** Many candidates drew arrows which did not originate from an energy value horizontal from that of the reactants and:

- did not reach the peak of the activation energy 'hump' for $E_a$
- did not reach an energy value equivalent to that of the products for $\Delta H$.

The direction of each arrow is important. $E_a$ should be indicated by an upwardly headed arrow and $\Delta H$ by a downwardly headed arrow. Double headed arrows are incorrect as they do not indicate the endothermic/exothermic nature of the change.

**(iv)** The definition of activation energy is new to the syllabus. Many candidates wrote 'minimum energy to start a reaction' but only a few attempted to define activation energy in terms of colliding particles reacting.

**(v)** Although the majority knew that adding (or removing) a catalyst would change the activation energy, many incorrectly thought that changing the temperature would alter the activation energy.

**(c)** Candidates were confident in performing the two calculations involving bond energies and the answers 3200 kJ and 1610 kJ were frequently seen.

Common errors were:

- Omitting two O–H bonds and arriving at a value of 2280 kJ for the first answer.
- Misreading the question and adding the $\Delta H$ value of 130 kJ to 1610 kJ to give 1740 kJ.
- Many candidates were unable to incorporate the $\Delta H$ value of 130 kJ correctly into their calculation to find the total H–C$l$ bond energy.

**Question 6**

**(a)** Many candidates performed well. Some candidates repeated a phrase from the question in their answer which stated '… members have similar chemical properties'. This approach is unlikely to gain credit.

**(b)** Relatively few candidates knew the difference was a $–CH_2–$ unit.

**(c) (i)** Most candidates performed well here, and all three homologous series were known.

**(ii)** The name, propanoic acid, was well known. Candidates should be aware that spelling is important for organic chemicals. Propenoic acid suggests the presence of an alkene group. Candidates are also expected to show every atom and every bond in a displayed formula. Frequently, the –O–H bond was left as –OH.

**(d) (i)** Many candidates found this question challenging and did not know how to approach it. Addition of the relative atomic masses was not done in a systematic manner and atoms were omitted. Sometimes atomic numbers were used instead. Often only a numerical answer was given without a formula being attempted.

**(ii)** Most candidates knew the name given to natural polyamides was proteins.

# CHEMISTRY

**Paper 0971/62**
**Paper 6 Alternative to Practical**

## Key messages

- When plotting graphs, points should be plotted as a cross (×) or an encircled dot (⊙) and not obscured by the graph line, which should be drawn using a sharp pencil. Lines of best fit should be smooth curves or ruler-drawn straight lines and should not wobble from point to point. Candidates will need to decide if the points lie on a straight line or 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 on page 49 in the section entitled 'Graphs' (and also recommended by the Association for Science Education (ASE)).

- 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, 'The student tests for any gas produced' 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 always acceptable. However, if a candidate answers with an incorrect formula, then credit will not be awarded.

- In qualitative analysis, not all 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

Most candidates successfully attempted all the questions and the full range of marks was seen. Most candidates were able to complete all questions in the time available. The paper was generally well answered, with very few blank spaces.

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. 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)** Most candidates were able to name the apparatus required as a pestle and mortar.

**(b)** Most candidates were able to correctly state that excess dilute hydrochloric acid was necessary to ensure that all the calcium carbonate in the seashells reacts. A few candidates incorrectly stated that all the acid would react or gave answers based on reaction rate.

**(c)** Most candidates correctly identified the funnel and the conical flask. The most common errors were to identify **A** as a filter and **B** as a beaker. 'Filter funnel' is acceptable but 'filter' on its own is not. It should be noted that **A** is not a separating funnel, although it is used to separate a solid from a liquid. The term separating funnel is the name used for apparatus with a tap that is used to separate immiscible liquids of differing densities.

**(d) (i)** Most candidates correctly stated that the impurity is calcium chloride (the salt made during the reaction) or hydrochloric acid (which was added in excess). A significant number of other candidates identified the impurity as a gas (commonly carbon dioxide) or silicon(IV) oxide – which is the substance that is being isolated by filtration and makes up most of the residue.

**(ii)** Almost all candidates realised that the mass of the residue had to be found. Few candidates realised that the residue needed to be dried before the mass was found.

**Question 2**

**(a)** Almost all candidates gained credit for recording the volumes of aqueous sodium hydroxide. A small number of candidates did not record the thermometer readings to half a scale division – and so incorrectly recorded the reading for experiment 4 as 30 °C or 31 °C rather than 30.5 °C, or for experiment 6 as 27 °C or 28 °C rather than 27.5 °C. Credit was awarded for having all thermometer readings and volumes recorded to 1 decimal place. Most candidates did this for the masses; they often did not do this for the temperatures, for example recording 26 °C rather than 26.0 °C.

**(b)** Many fully correct graphs were seen. Common errors included:

- Use of inappropriate graph scales. The expected graph scale was each large grid square being equivalent to 2 °C. In this case candidates were told that the scale on the *y*-axis should extend by at least 2 °C above the highest temperature in Table 2.1, meaning the scale should have extended to at least 32.5 °C. The expectation was that the scale, from 26.0 °C to 32.5 °C, would take up over half of the available space on the *y*-axis. Most scales selected did not meet this requirement. It was very common for scales to be chosen where each large grid square was equivalent to 6.5 or 7.0 °C. Candidates who chose awkward scales very often plotted points incorrectly.
- As well as plotting errors caused by the selection of a difficult scale, it was common for candidates to plot the data for experiments 4, 5 and 6 at volumes of 4.0, 5.0 and 6.0 $cm^3$ rather than volumes of 6.0, 7.0 and 8.0 $cm^3$.
- A minority of candidates did not extend their lines so that they crossed.

**(c) (i)** Most candidates indicated on the graph where they were taking their reading from and correctly recorded the volume of dilute hydrochloric acid. Few candidates then calculated the volume of aqueous sodium hydroxide. Instead, they recorded the temperature at the indicated point on their graph. The expected answer was that the volume of aqueous sodium hydroxide was evaluated to be 10 minus the volume of dilute hydrochloric acid; this is because the total volume in each experiment was 10 $cm^3$.

**(ii)** This question proved to be demanding. In the stem to **(c)**, candidates were told that at the point where the lines cross, a neutral solution is formed. Hence, the expected answer was pH 7.

**(iii)** This required a comparison of the two volumes recorded in **(c)(i)**. An error carried forward from the volumes recorded was allowed. The expected answer was that the hydrochloric acid was the more concentrated because a lower volume of it was required to produce a neutral solution. A very common error was to state that the sodium hydroxide was more concentrated because it had a larger volume.

**(d)** Most candidates realised that the polystyrene would act as an insulator; many did not realise that because this is an exothermic reaction, it would mean that less heat energy would be lost resulting in a higher temperature.

**(e)** Better performing candidates could explain why a volumetric pipette could not be used. Some candidates were confused between volumetric pipettes and teat or Pasteur pipettes. A volumetric pipette has a single graduation line and will accurately measure only one specific volume; as this experiment required a variety of different volumes, a volumetric pipette would not be able to measure them all.

**Question 3**

**(a) (i)** Most candidates correctly stated that **K** could contain zinc ions or aluminium ions.

**(ii)** Most candidates correctly suggested adding excess aqueous ammonia, which would cause any precipitate caused by zinc ions to redissolve. Common errors were to state that drops of ammonia could be added, which must be incorrect as that is the test that has just been done, or to use aqueous sodium hydroxide, which would give the same result for both zinc and aluminium ions.

**(b)** Most candidates correctly stated that the anion was the bromide ion.

**(c)** With the 'Notes for use in qualitative analysis' now included on the examination paper, almost all candidates were able to state that a green flame would be seen.

**(d)** In this question, candidates were told that the student tested for any gas produced. Answers should have included the test and result for the gas that was produced – in this case the gas was ammonia and so candidates should have noted that damp red litmus paper turned blue. The most common error was to just state that the gas made was ammonia; this is not an observation and so did not gain credit.

**(e)** The test was the test for a halide ion. As **L** is barium nitrate, it does not contain a halide ion and so there would have been no reaction. Candidates found negative tests more difficult than positive tests, but they should be familiar with them as they provide useful information by showing what something is not.

**(f)** This proved to be the most demanding part of **Question 3**. The better performing candidates realised that aqueous barium nitrate is used in the test for sulfate ions and so a white precipitate will be formed.

**Question 4**

Some excellent and succinct descriptions of this quantitative task were seen, with better performing candidates gaining full credit.

By far the most common error was for candidates to think that solubility referred to how quickly something dissolved rather than how much of something would dissolve. Answers based on time taken to dissolve rather than the mass that would dissolve did not gain full credit.

As this was a quantitative task, credit was available for controlling the quantities used; these were the **mass** of sodium sulfate and the **volume** of water. The term 'amount' is not credited when a mass or a volume is required.

There were several possible routes through this quantitative planning task. All methods should have included:

- use of a known/measured/stated volume of water
- use of a known/measured/stated mass of sodium sulfate
- use of an appropriate named container – such as a beaker
- stirring the mixture of water and sodium sulfate to aid dissolution
- repeating the method at different temperatures.

The most common correct methods were to add a known mass of sodium sulfate to a fixed volume of water, remove the sodium sulfate that had not dissolved by filtration and determine the mass of the undissolved sodium sulfate after drying.

It should be noted that there is no need for candidates to write a list of aims, apparatus nor independent, dependent and control variables at the start of their responses. The aim of the plan is already given in the question and credit will not be awarded for listing items of apparatus. Where credit is available for the selection of an appropriate item of apparatus, then it must be clear in the plan for what the item of apparatus will be used.