Caroline Chisholm School
Ambition Confidence Success
Everyone Every Lesson Every Opportunity

AQA
GCSE
CHEMISTRY
PAPER 1
REVISION BOOKLET

Name:.................. Class: ....

AQA GCSE Chemistry Paper 1 Content

For your End of Year exam, you will be sitting a full AQA GCSE Chemistry Paper 1. You will be examined on the following topics.

What's assessed	Time	Marks available
• Atomic Structure and the Periodic Table • Bonding, Structure and the Properties of Matter • Quantitative Chemistry • Chemical Changes • Energy Changes	1 hr 45 mins	100

Atomic Structure and the Periodic Table	
1. Atomic structure - Atoms - Chemical equations - Separating mixtures - Fractional distillation and paper chromatography - History of the atom - Structure of the atom - Ions, atoms and isotopes - Electronic structure	**2. The Periodic Table** - Development of the Periodic Table# - Electronic structures and the Periodic Table - Group 1 – the alkali metals - Group 7 – the halogens - Explaining trends - *The transition elements (Chemistry only)*

Bonding, Structure and the Properties of Matter	
3. Structure and bonding - States of matter - Atoms into ions - Ionic bonding - Giant ionic structures - Covalent bonding - Structure of simple molecules - Giant covalent structures - Fullerenes and graphene - Bonding in metals - Giant metallic structures - *Nanoparticles (Chemistry only)* - *Applications of nanoparticles (Chemistry only)*	

Quantitative Chemistry	
4. Chemical calculations - Relative masses and moles - Equations and calculations - From masses to balanced equations - *<u>The yield of a chemical reaction (Chemistry only)</u>* - *<u>Atom economy (Chemistry only)</u>* - Expressing concentrations - *<u>Titrations (Chemistry only)</u>* - *<u>Titration calculations (Chemistry only)</u>* - *<u>Volumes of gases (Chemistry only)</u>* **Required Practical:** Neutralization – Use titration to find out how much of an acid is needed to completely react with the alkali	-

Chemical Changes	
5. Chemical changes - The reactivity series - Displacement reactions - Extracting metals - Salts from metals - Salts from insoluble bases - Making more salts - Neutralisation and the pH scale - Strong and weak acids **Required Practical:** Making salts – Prepare with the appropriate apparatus and techniques, a pure, dry sample of a soluble salt from an insoluble carbonate or oxide	**6. Electrolysis** - Introduction to electrolysis - Changes at the electrodes - The extraction of aluminium - Electrolysis of aqueous solutions **Required Practical:** Electrolysis – Investigate the electrolysis of different aqueous solutions using inert electrodes

Energy Changes	
7. Energy changes - Exothermic and endothermic reactions - Using energy transfers from reactions - Reaction profiles - Bond energy calculations - *<u>Chemical cells and batteries (Chemistry only)</u>* - *<u>Fuel cells (Chemistry only)</u>*	-

C1: Atomic Structure – papers 1 & 2

Lesson	Aiming for 4	Aiming for 6	Aiming for 8
C1.1 Atoms	I can define the word element.	I can describe the basic structure of an atom.	I can use chemical symbols of atoms to produce the chemical formulae of a range of elements and compounds.
	I can classify familiar substances as elements or compounds.	I can explain in detail, including diagrams, the difference between a pure element, mixture and compound.	I can explain the significance of chemical symbols used in formulae and equations.
	I can use the periodic table to find the symbols or names of given elements.	I can name and give the chemical symbol of the first 20 elements in the periodic table.	
C1.2 Chemical equations	I can describe familiar chemical reactions in word equations.	I can explain why mass is conserved in a chemical reaction.	I can justify in detail how mass may appear to change in a chemical reaction.
	I can state that mass is conserved in a chemical reaction.	I can describe familiar chemical reactions with balanced symbol equations including state symbols.	I can describe unfamiliar chemical reactions with more complex balanced symbol equations, including state symbols.
		I can balance given symbol equations.	I can write balanced symbol equations.
C1.3 Separating mixtures	I can define the word 'mixture'.	I can explain the difference between a compound and a mixture.	I can use experimental data to explain the classification of a substance as a compound or a mixture.
	I can identify a mixture and a compound.	I can explain how the chemical properties of a mixture relate to the chemical it is made from.	I can suggest an appropriate separation or purification technique for an unfamiliar mixture.
	I can list different separation techniques.	I can describe different separation techniques.	I can explain in detail how multi-step separation techniques work.
C1.4 Fractional distillation and paper chromatography	I can state when fractional distillation would be used.	I can describe the process of fractional distillation.	I can explain in detail how fractional distillation can separate miscible liquids with similar boiling points.
	I can safely make a paper chromatogram.	I can explain the main processes occurring in paper chromatography.	I can evaluate separation or purification techniques for a given mixture.
C1.5 History of the atom	I can list the significant models proposed for atoms.	I can describe the differences between the plum-pudding and the nuclear model of the atom.	I can justify why the model of the atom has changed over time.
	I can identify the key parts of the plum-pudding model and the nuclear model of the atom.	I can explain how evidence from scattering experiments changed the model of the atom.	I can evaluate the current model of an atom.
C1.6 Structure of the atom	I can state the relative charges and masses of subatomic particles.	I can describe atoms using the atomic model.	I can use the periodic table to find atomic number and mass number data and use it to determine the number of each subatomic particle in any given atom.
	I can state that atoms have no overall charge (are neutral).	I can explain why atoms have no overall charge.	I can recognise and describe patterns in subatomic particles of elements listed in the periodic table.
	I can label the subatomic particles on a diagram of a helium atom.	I can use atomic number and mass numbers of familiar atoms to determine the number of each subatomic particle.	I can explain why we can be confident that there are no missing elements in the first 10 elements of the periodic table.
C1.7 Ions, atoms, and isotopes	I can state what an ion is.	I can describe isotopes using the atomic model.	I can use the periodic table to find atomic number and mass number data and use it to determine the number of each subatomic particle in an ion.
	I can define an isotope.	I can explain why ions have a charge.	I can use SI units and prefixes to describe the size of an atom and its nucleus in standard form.
	I can state the relative sizes of an atom and its nucleus.	I can use atomic number and mass numbers of familiar ions to determine the number of each subatomic particle.	I can explain why chlorine does not have a whole mass number.

C1: Atomic Structure – papers 1 & 2

C1.8 Electronic structures	I can state that electrons are found in energy levels of an atom.	☐ ☐	I can write the standard electronic configuration notation from a diagram for the first 20 elements.	☐ ☐	I can use the periodic table to find atomic number and determine the electronic structure for the first 20 elements .	☐ ☐
	I can state the maximum number of electrons in the first three energy levels.		I can explain why elements in the same group react in a similar way .		I can make predictions for how an element will react when given information on another element in the same group.	

C2: The periodic table - papers 1 & 2

Lesson	Aiming for 4		Aiming for 6		Aiming for 8	
C2.1 Development of the periodic table	I can list the significant models for ordering the elements.	☐	I can describe how the elements are arranged in groups and periods in the periodic table.	☐	I can explain how and why the ordering of the elements has changed over time.	☐
	I can state how the elements are ordered in the periodic table.	☐	I can explain why the periodic table was a breakthrough in how to order elements.	☐		
C2.2 Electronic structures and the periodic table	I can define a group and period in the periodic table.	☐	I can describe how the electronic structure of metals and non-metals are different.	☐	I can explain how the electronic structure of metals and non-metals affects their reactivity.	☐
	I can describe how electronic structure is linked to the periodic table.	☐	I can explain in terms of electronic structure how the elements are arranged in the periodic table.	☐	I can use the periodic table to make predictions about the electronic structure and reactions of elements.	☐
	I can state that noble gases are unreactive.	☐	I can explain why the noble gases are unreactive and the trend in their boiling points.	☐	I can predict the electronic structure of stable ions for the first 20 elements.	☐
C2.3 Group 1- the alkali metals	I can name the first three elements in Group 1.	☐	I can recognise trends in supplied data.	☐	I can illustrate the reactions of Group 1 metals with balanced symbol equations.	☐
	I can describe the Group 1 metals as having low densities.	☐	I can explain why the elements in Group 1 react similarly and why the first three elements float on water.	☐	I can explain how Group 1 metals form ions with a +1 charge when they react with non-metals.	☐
	I can write word equations from descriptions of how Group 1 metals react with water.	☐	I can Describe how you can show that hydrogen and metal hydroxides are made when Group 1 metals react with water.	☐	I can justify how Group 1 metals are stored and the safety precautions used when dealing with them.	☐
C2.4 Group 7- the halogens	I can name the first four elements in Group 7.	☐	I can recognise trends in supplied data.	☐	I can illustrate the reactions of Group 7 metals with balanced symbol equations.	☐
	I can recognise a halogen displacement reaction.	☐	I can explain why the elements in Group 7 react similarly.	☐	I can explain how Group 7 non-metals form ions with a −1 charge when they react with metals.	☐
	I can describe the main properties of halogens.	☐	I can explain how to complete a halogen displacement reaction and explain what happens in the reaction.	☐	I can explain in detail how to compare the reactivity of the Group elements.	☐
C2.5 Explaining trends	I can state the trend in reactivity in Group 1.	☐	I can explain how electronic structure affects the trend in reactivity of Group 1 and Group 7 elements.	☐	I can use electronic structure to explain the trends in physical and chemical properties of Group 1 and Group 7 elements.	☐
	I can state the trend in reactivity in Group 7.	☐	I can use the nuclear model to explain how the outer electrons experience different levels of attraction to the nucleus.	☐	I can apply knowledge of reactivity of Groups 1 and 7 to suggest and explain the trend in reactivity of Group 2 and 6.	☐
C2.6 The transition elements	I can list the typical properties of transition metals and their compounds.	☐	I can describe how the properties of Group 1 metals compare with transition metals.	☐	I can justify the use of a transition metal or its compound in terms of its chemical properties.	☐
	I can explain why mercury is not a typical transition element.	☐	I can interpret the formula and names of familiar transition metal compounds.	☐	I can suggest why Group 1 metals have different properties compared to transition metals.	☐

C3 Structure and Bonding – papers 1 & 2

Lesson	Aiming for 4		Aiming for 6		Aiming for 8	
C3.1 States of matter	I can identify the three states of matter and their state symbols.	☐	I can use data to determine the state of a substance at a given temperature.	☐	I can use the particle model to describe how energy, movement, and attraction between particles changes as a substance is heated or cooled.	☐
	I can describe the process of melting, freezing, boiling, and condensing.	☐	I can explain, in terms of particles, energy and temperature of a substance when it is at the melting point or boiling point.	☐	I can suggest why substances have different melting and boiling points from each other.	☐
	I can use the particle model to draw a representation of how particles are arranged in the three states of matter.	☐	I can describe the factors that affect rate of evaporation.	☐	I can evaluate a model, explaining its limitations. (H)	☐
C3.2 Atoms in ions	I can state the particles involved in ionic and covalent bonding.	☐	I can draw dot and cross diagrams of compounds formed between Group 1 and Group 7 elements.	☐	I can draw dot and cross diagrams of unfamiliar ionic compounds.	☐
	I can describe, with an example, how a Group 1 metal atom becomes a positive ion.	☐	I can explain how electron transfer allows ionic bonding to occur in the compound formed when a Group 1 metal reacts with a Group 7 non-metal.	☐	I can suggest and explain the charge of a monatomic ion based on its position in the periodic table.	☐
	I can describe, with an example, how a Group 7 non-metal atom becomes a negative ion.	☐				
C3.3 Ionic bonding	I can state that opposite charges attract.	☐	I can explain how the position of an element on the periodic table relates to the charge on its most stable monatomic ion.	☐	I can suggest the charge on unfamiliar ions using the position of the element in the periodic table.	☐
	I can write the charges of ions of Group 1, Group 2, Group 6, and Group 7 elements.	☐	I can explain, in terms of electronic structure, how unfamiliar elements become ions.	☐	I can explain the ratio of metal and non-metal ions in compounds.	☐
	I can describe an ionic lattice.	☐	I can interpret formula of familiar ionic compounds to determine the number and type of each ion present.	☐	I can generate formula of a wide range of ionic compounds when the charges of the ions are given.	☐
C3.4 Giant ionic structures	I can state that ionic compounds have high melting points and can dissolve in water.	☐	I can explain why ionic compounds have a high melting point.	☐	I can explain in detail why ionic compounds cannot conduct electricity when they are solid but can when molten or in solution.	☐
	I can state that ionic compounds can conduct electricity when molten or dissolved in water.	☐	I can describe, in terms of ions, how an ionic compound can conduct electricity.	☐	I can justify in terms of properties that a compound has ionic bonding.	☐
	I can describe an ionic lattice.	☐	I can explain the movement of ions in solutions or when molten.	☐	I can apply the ionic model to make predictions of the physical properties of ionic compounds.	☐
C3.5 Covalent bonding	I can describe a covalent bond.	☐	I can explain how a covalent bond forms in terms of electronic structure.	☐	I can draw dot and cross diagrams and ball and stick diagrams for unfamiliar small molecules.	☐
	I can recognise a covalent compound from its formula, name, or diagram showing bonds.	☐	I can draw dot and cross diagrams and ball and stick diagrams for H_2, Cl_2, O_2, N_2, HCl, H_2O, NH_3, and CH_4.	☐	I can suggest how double and triple covalent bonds can be formed.	☐
	I can name familiar examples of small molecules which contain covalent bonds.	☐	I can describe a double bond in a diatomic molecule.	☐	I can suggest how the properties of a double bond could be different to the properties of a single covalent bond.	☐
C3.6 Simple molecules	I can state that small molecules have low melting and boiling points.	☐	I can explain how the size of molecules affects melting and boiling points	☐	I can predict the physical properties of unfamiliar covalently bonded substances.	☐
	I can state that small molecules do not conduct electricity.	☐	I can explain why small molecules and polymers do not conduct electricity.	☐	I can compare and contrast the properties of substances with different bonding.	☐

C3 Structure and Bonding – papers 1 & 2

	I can describe an intermolecular force.	☐	I can identify substances that would have weak intermolecular forces.	☐	I can justify the use of a model to explain the physical properties of a small molecule and discuss the limitations of various molecular models.	☐
C3.7 Giant covalent structures	I can list the main physical properties of diamond and graphite.	☐	I can recognise the structure of diamond and graphite from information provided in written or diagrammatic form.	☐	I can use a molecular model of an unfamiliar giant covalent structure to predict and explain is physical properties.	☐
	I can state that giant covalent structures have high melting points.	☐	I can explain the properties of diamond in terms of its bonding.	☐	I can justify in detail a use for graphite based on its properties.	☐
	I can describe the structure of graphite in terms of layers of carbon atoms.	☐	I can explain the properties of graphite in terms of its bonding.	☐	I can justify in detail a use for diamond based on its properties.	☐
C3.8 Fullerenes and graphene	I can describe the relationship between graphite and graphene.	☐	I can recognise the structure of a fullerene or nanotube in diagrams and prose.	☐	I can describe and explain the applications of fullerenes.	☐
	I can list the main physical properties of fullerenes.	☐	I can explain the structure of fullerenes.	☐	I can use molecular models of graphene, nanotubes, and fullerenes to explain their properties.	☐
	I can state the molecular formula of buckminsterfullerene.	☐	I can list the properties and consequent uses of fullerenes and carbon nanotubes.	☐	I can justify in detail a use for graphene, nanotubes and fullerenes, based on their properties.	☐
C3.9 Bonding in metals	I can state that metals form a giant structure.	☐	I can describe metallic bonding.	☐	I can explain how metal atoms form giant structures.	☐
	I can recognise metallic bonding in diagrams.	☐	I can recognise and represent metallic bonding diagrammatically.	☐	I can evaluate different models of metallic bonding.	☐
C3.10 Bonding in metals	I can list the physical properties of metals.	☐	I can explain key physical properties of metals using the model of metallic bonding.	☐	I can explain in detail, including labelled diagrams, how alloying affects the structure and bonding in metals and its effect on properties.	☐
	I can describe the structure of a pure metal.	☐	I can describe why metals are alloyed.	☐	I can justify in detail why alloys are more often used than pure metals.	☐
C3.11 Nanoparticles	I can state a definition of nanoscience.	☐	I can describe the size of nanoparticles.	☐	I can classify a particle as coarse, fine, or nanoparticles based on their size.	☐
	I can describe how surface area to volume increases as particle size reduces.	☐	I can explain why surface area to volume ratio increases as particle size decrease.	☐	I can quantitatively explain the relationship between surface area to volume ratio and particle size and its effect on properties.	☐
	I can recognise that the negative indices in standard form used in nanoscience are very small numbers.	☐	I can convert lengths into standard form.	☐	I can convert standard form into a variety of length units.	☐
C3.12 Applications of nanoscience	I can state that nanoparticles can be used in sun cream.	☐	I can list the advantages and disadvantages of using nanoparticles.	☐	I can evaluate the use of nanoparticles in their applications, including sun cream.	☐
	I can list a variety of uses of nanoparticles.	☐	I can explain why nanoparticles can have new applications.	☐	I can decide and justify in detail why nanotechnology research should continue.	☐

C4: Chemical calculations - Paper

Lesson	Aiming for 4	Aiming for 6	Aiming for 8
C4.1 Relative masses and moles	I can use the periodic table to identify the relative atomic mass for the first 20 elements.	I can use the periodic table to find the relative atomic mass of all elements.	I can explain why some elements have the same relative atomic mass as each other and why relative atomic masses may not be a whole number.
	I can calculate the relative formula mass for familiar compounds when the formula is supplied and is without brackets.	I can calculate the relative formula mass for unfamiliar compounds when the formula is given.	I can calculate the number of moles or mass of a substance from data supplied.
		I can state the units for the amount of substance.	I can convert between units in calculations.
(H) C4.2 Equations and calculations		I can explain why chemical equations must be balanced.	I can interpret balanced symbol equations in terms of mole ratios.
		I can calculate the relative formula mass for one substance when the relative formula masses are given for all the other substances in a balanced symbol equation.	I can use balanced symbol equations to calculate reacting masses.
(H) C4.3 From masses to balanced equations		I can explain why chemical equations must be balanced.	I can explain the effect of a limiting reactant on the amount of product made.
		I can identify the limiting reactant in a chemical reaction.	I can use balanced symbol equations to calculate reacting masses when there is a limiting reactant.
C4.4 Yield of a chemical reaction	I can state the definition of theoretical yield, actual yield, and percentage yield.	I can calculate percentage yield when the actual yield is given and the mass of the limiting reactant is given.	I can calculate the percentage yield using a variety of units and conversions.
	I can calculate percentage yield when actual yield and theoretical yield are given.	I can list reasons why actual yield is often lower than theoretical yield.	I can justify why percentage yield can never be above 100%.
C4.5 Atom economy	I can calculate the formula mass of substances when the formula is given.	I can calculate the atom economy for a given chemical reaction.	I can evaluate different reactions to decide the best production method of a chemical.
	I can recognise a covalent compound from its formula, name, or diagram showing bonds.	I can explain why using reactions with high atom economy is important.	I can explain why the sum of the formula masses of the reactants is the same as the sum of the formula masses of the products.
	I can state a definition of atom economy.		
(H) C4.6 Expressing concentrations		I can explain how concentration of a solution can be changed.	I can calculate the concentration of a solution when the number of moles and volume in cm^3 is given.
		I can calculate the concentration, in mol/dm^3, of a solution when the number of moles and volume in dm^3 is given.	I can calculate the mass of a chemical when any volume and concentration is given and independently express their answers to an appropriate number of significant figures.
		I can calculate the concentration of a solution in g/dm^3 of a solution when the number of moles and volume in dm^3 is given.	I can calculate the amount of solute in a solution using the concentration of the solution.
C4.7 Titrations		I can calculate a titre.	I can justify the use of a pipette and burette for a titration, evaluating the errors involved in reading these instruments.
		I can describe how an indicator can be used to determine the end point.	I can explain how precise results are obtained in a titration.
		I can explain how accuracy can be improved in a titration.	I can justify the use of an indicator in an acid-base titration.
(H)		I can calculate the amount of acid or alkali needed in a neutralisation reaction.	I can calculate the unknown concentration of a reactant in a neutralisation reaction when the volumes are known and the concentration of one reactant is also known.

C4: Chemical calculations - Paper

C4.8 Titration calculations		I can convert units.	☐	I can extract data from given information to perform multi-step calculations independently.	☐
H C4.9 Volumes of gases		I can calculate the amount in moles of gas in a given volume at room temperature and pressure.	☐	I can suggest how the volume of gas would change when temperature or pressure was changed.	☐
		I can convert units.	☐	I can calculate the moles or volume of a gaseous substance involved in a chemical reaction.	☐

Chapter 1: Atomic structure

Knowledge organiser

Development of the model of the atom

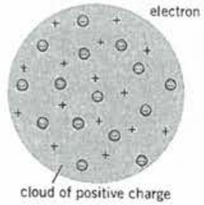
Dalton's model

John Dalton thought of the **atom** as a solid sphere that could not be divided into smaller parts. His model did not include **protons**, **neutrons**, or **electrons**.

The plum pudding model

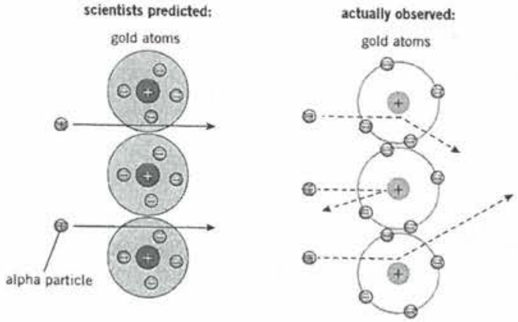
Scientists' experiments resulted in the discovery of sub-atomic charged particles. The first to be discovered were electrons – tiny, negatively charged particles.

The discovery of electrons led to the plum pudding model of the atom – a cloud of positive charge, with negative electrons embedded in it. Protons and neutrons had not yet been discovered.



Alpha scattering experiment

1. Scientists fired small, positively charged particles (called alpha particles) at a piece of gold foil only a few atoms thick.
2. They expected the alpha particles to travel straight through the gold.
3. They were surprised that some of the alpha particles bounced back and many were deflected (alpha scattering).
4. To explain why the alpha particles were repelled the scientists suggested that the positive charge and mass of an atom must be concentrated in a small space at its centre. They called this space the **nucleus**.

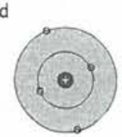


Nuclear model

Scientists replaced the plum pudding model with the nuclear model and suggested that the electrons **orbit** the nucleus, but not at set distances.

Electron shell (Bohr) model

Niels Bohr calculated that electrons must orbit the nucleus at fixed distances. These orbits are called **shells** or **energy levels**.



The proton

Further experiments provided evidence that the nucleus contained smaller particles called protons. A proton has an opposite charge to an electron.

The neutron

James Chadwick carried out experiments that gave evidence for a particle with no charge. Scientists called this the neutron and concluded that the protons and neutrons are in the nucleus, and the electrons orbit the nucleus in shells.

Relative mass

One property of protons, neutrons, and electrons is **relative mass** – their masses compared to each other. Protons and neutrons have the same mass, so are given a relative mass of 1. It takes almost 2000 electrons to equal the mass of a single proton – their relative mass is so small that we can consider it as 0.

Size

The atom has a radius of 1×10^{-10} m. Nuclei (plural of nucleus) are around 10 000 times smaller than atoms and have a radius of around 1×10^{-14} m.

Elements and compounds

Elements are substances made of one type of atom. Each atom of an element will have the same number of protons.

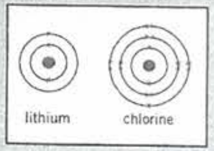
Compounds are made of different types of atoms chemically bonded together. The atoms in a compound have different numbers of protons.

Drawing atoms

Electrons in an atom are placed in fixed shells. You can put

- up to two electrons in the first shell
- eight electrons each in the second and third shells.

You must fill up a shell before moving on to the next one.



Mixtures

- A mixture consists of two or more elements or compounds that are not chemically combined together.
- The substances in a mixture can be separated using physical processes.
- These processes do not use chemical reactions.

Separating mixtures

- filtration – insoluble solids and a liquid
- crystallisation – soluble solid from a solution
- simple distillation – solvent from a solution
- fractional distillation – two liquids with similar boiling points
- paper chromatography – identify substances from a mixture in solution

Atoms and particles

	Relative charge	Relative mass	
Proton	+1	1	= atomic number
Neutron	0	1	= mass number – atomic number
Electron	–1	0 (very small)	= same as the number of protons

All atoms have equal numbers of protons and electrons, meaning they have no overall charge:

total negative charge from electrons = total positive charge from protons

Isotopes

Atoms of the same element can have a different number of neutrons, giving them a different overall mass number. Atoms of the same element with different numbers of neutrons are called **isotopes**.

The **relative atomic mass** is the average mass of all the atoms of an element:

$$\text{relative atomic mass} = \frac{(\text{abundance of isotope 1} \times \text{mass of isotope 1}) + (\text{abundance of isotope 2} \times \text{mass of isotope 2})...}{100}$$

Key terms

Make sure you can write a definition for these key terms.

abundance atom atomic number aqueous compound electron element energy level isotope neutron nucleus orbit product proton reactant relative atomic mass relative charge relative mass shell

Chapter 1: Atomic structure

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C1 questions	Answers
1	What is an atom?	smallest part of an element that can exist
2	What is Dalton's model of the atom?	atoms as solid spheres that could not be divided into smaller parts
3	What is the plum pudding model of the atom?	sphere of positive charge with negative electrons embedded in it
4	What did scientists discover in the alpha scattering experiment?	some alpha particles were deflected by the gold foil – this showed that an atom's mass and positive charge must be concentrated in one small space (the nucleus)
5	Describe the nuclear model of the atom.	dense nucleus with electrons orbiting it
6	What did Niels Bohr discover?	electrons orbit in fixed energy levels (shells)
7	What did James Chadwick discover?	uncharged particle called the neutron
8	Where are protons and neutrons?	in the nucleus
9	What is the relative mass of each sub-atomic particle?	proton: 1, neutron: 1, electron: 0 (very small)
10	What is the relative charge of each sub-atomic particle?	proton: +1, neutron: 0, electron: −1
11	How can you find out the number of protons in an atom?	the atomic number on the Periodic Table
12	How can you calculate the number of neutrons in an atom?	mass number – atomic number
13	Why do atoms have no overall charge?	equal numbers of positive protons and negative electrons
14	How many electrons would you place in the first, second, and third shells?	up to 2 in the first shell and up to 8 in the second and third shells
15	What is an element?	substance made of one type of atom
16	What is a compound?	substance made of more than one type of atom chemically joined together
17	What is a mixture?	two or more substances not chemically combined
18	What are isotopes?	atoms of the same element (same number of protons) with different numbers of neutrons
19	What are the four physical processes that can be used to separate mixtures?	filtration, crystallisation, distillation, fractional distillation, chromatography
20	What is relative mass?	the average mass of all the atoms of an element

Put paper here

Chapter 2: The Periodic Table

Knowledge organiser

Development of the Periodic Table

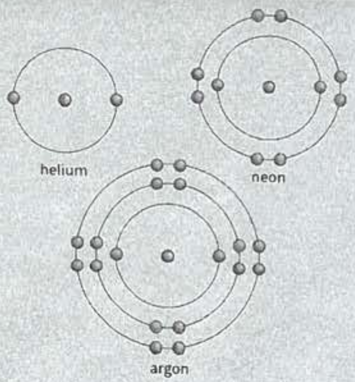
The Periodic Table has changed over time as scientists have organised it differently. Mendeleev was able to accurately predict the properties of undiscovered elements based on the gaps in the table.

	First lists of elements	Mendeleev's Periodic Table	Modern Periodic Table
How are elements ordered?	by atomic mass	normally by atomic mass but some elements were swapped around	by atomic number
Are there gaps?	no gaps	gaps left for undiscovered elements	no gaps – all elements up to a certain atomic number have been discovered
How are elements grouped?	not grouped	grouped by chemical properties	grouped by the number of electrons in the outer shells
Metals and non-metals	no clear distinction	no clear distinction	metals to the left, non-metals to the right
Problems	some elements grouped inappropriately	incomplete, with no explanation for why some elements had to be swapped to fit in the appropriate groups	—

Group 0

Elements in **Group 0** are called the **noble gases**. Noble gases have the following properties:

- full outer shells with eight electrons, so do not need to lose or gain electrons
- are very unreactive (**inert**) so exist as single atoms as they do not bond to form molecules
- boiling points that increase down the group.



Key terms

Make sure you can write a definition for these key terms.

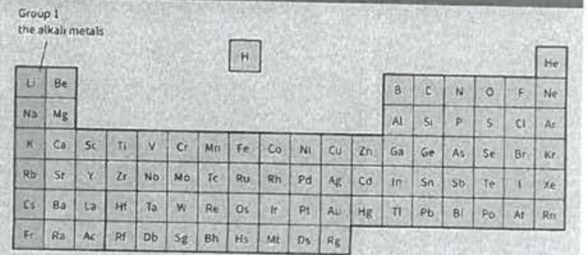
alkali metals, chemical properties, displacement, groups, halogens, inert, isotopes, noble gas, organised, Periodic Table, reactivity, undiscovered, unreactive

Group 1 elements

Group 1 elements react with oxygen, chlorine, and water, for example:

lithium + oxygen → lithium oxide
lithium + chlorine → lithium chloride
lithium + water → lithium hydroxide + hydrogen

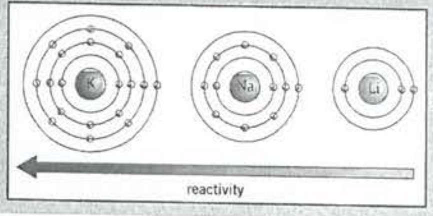
Group 1 elements are called **alkali metals** because they react with water to form an alkali (a solution of their metal hydroxide).



Group 1 properties

Group 1 elements all have one electron in their outer shell. **Reactivity** increases down Group 1 because as you move down the group:

- the atoms increase in size
- the outer electron is further away from the nucleus, and there are more shells shielding the outer electron from the nucleus
- the electrostatic attraction between the nucleus and the outer electron is weaker so it is easier to lose the one outer electron
- the melting point and boiling point decreases down Group 1.



Group 7 elements

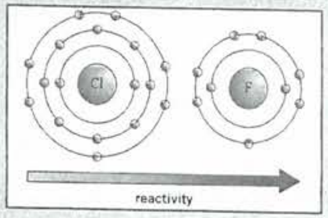
Group 7 elements are called the **halogens**. They are non-metals that exist as molecules made up of pairs of atoms.

Name	Formula	State at room temperature	Melting point and boiling point	Reactivity
fluorine	F_2	gas	increases down the group	decreases down the group
chlorine	Cl_2	gas		
bromine	Br_2	liquid		
iodine	I_2	solid		

Group 7 reactivity

Reactivity decreases down Group 7 because as you move down the group:

- the atoms increase in size
- the outer shell is further away from the nucleus, and there are more shells between the nucleus and the outer shell
- the electrostatic attraction from the nucleus to the outer shell is weaker so it is harder to gain one electron to fill the outer shell.



Group 7 displacement

More reactive Group 7 elements can take the place of less reactive ones in a compound. This is called **displacement**.
For example, fluorine displaces chlorine as it is more reactive:

fluorine + potassium chloride → potassium fluoride + chlorine

Chapter 2: The Periodic Table

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C2 questions	Answers
1	How is the modern Periodic Table ordered?	by atomic number
2	How were the early lists of elements ordered?	by atomic mass
3	Why did Mendeleev swap the order of some elements?	to group them by their chemical properties
4	Why did Mendeleev leave gaps in his Periodic Table?	leave room for elements that had not yet been discovered
5	Why do elements in a group have similar chemical properties?	have the same number of electrons in their outer shell
6	Where are metals and non-metals located on the Periodic Table?	metals to the left, non-metals to the right
7	What name is given to the Group 1 elements?	alkali metals
8	Why are the alkali metals named this?	they are metals that react with water to form an alkali
9	Give the general equations for the reactions of alkali metals with oxygen, chlorine, and water.	metal + oxygen → metal oxide metal + chlorine → metal chloride metal + water → metal hydroxide + hydrogen
10	How does the reactivity of the alkali metals change down the group?	increases (more reactive)
11	Why does the reactivity of the alkali metals increase down the group?	they are larger atoms, so the outermost electron is further from the nucleus, meaning there are weaker electrostatic forces of attraction and more shielding between the nucleus and outer electron, and it is easier to lose the electron
12	What name is given to the Group 7 elements?	halogens
13	Give the formulae of the first four halogens.	F_2, Cl_2, Br_2, I_2
14	How do the melting points of the halogens change down the group?	increase (higher melting point)
15	How does the reactivity of the halogens change down the group?	decrease (less reactive)
16	Why does the reactivity of the halogens decrease down the group?	they are larger atoms, so the outermost shell is further from the nucleus, meaning there are weaker electrostatic forces of attraction and more shielding between the nucleus and outer shell, and it is harder to gain an electron
17	What is a displacement reaction?	when a more reactive element takes the place of a less reactive one in a compound
18	What name is given to the Group 0 elements?	noble gases
19	Why are the noble gases inert?	they have full outer shells so do not need to lose or gain electrons
20	How do the melting points of the noble gases change down the group?	increase (higher melting point)

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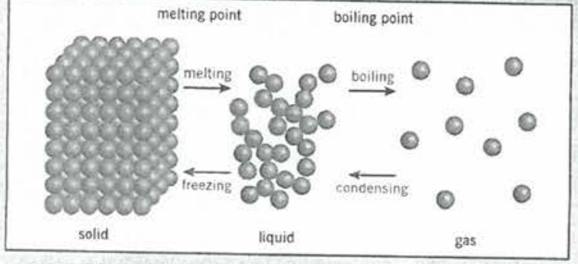
Chapter 3: Bonding 1

Knowledge organiser

Particle model

The three states of matter can be represented in the particle model.



(HT only) This model assumes that:

- there are no forces between the particles
- that all particles in a substance are spherical
- that the spheres are solid.

The amount of energy needed to change the state of a substance depends on the forces between the particles. The stronger the forces between the particles, the higher the melting or boiling point of the substance.

Covalent bonding

Atoms can share or transfer electrons to form strong chemical bonds.

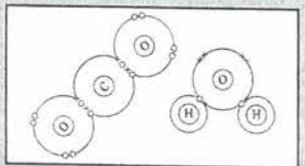
A **covalent bond** is when electrons are *shared* between **non-metal** atoms.

The number of electrons shared depends on how many extra electrons an atom needs to make a full outer shell.

If you include electrons that are shared between atoms, each atom has a full outer shell.

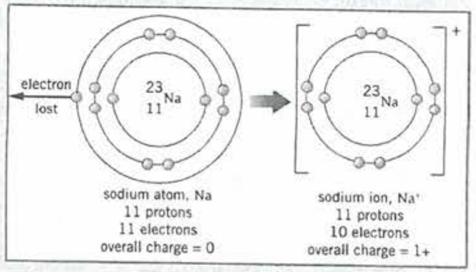
Single bond = each atom shares one pair of electrons.

Double bond = each atom shares two pairs of electrons.



Ions

Atoms can gain or lose electrons to give them a full outer shell. The number of protons is then different from the number of electrons. The resulting particle has a charge and is called an **ion**.



Conductivity

Solid ionic substances do not conduct electricity because the ions are fixed in position and not free to carry charge.

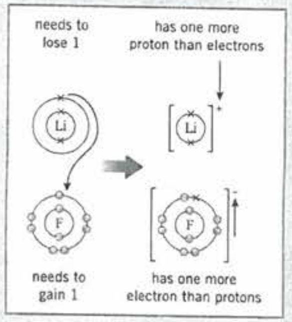
When melted or dissolved in water, ionic substances do conduct electricity because the ions are free to move and carry charge.

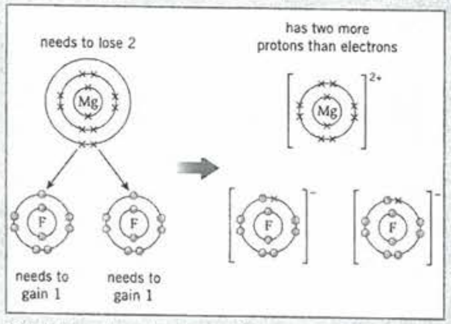
Melting points

Ionic substances have high melting points because the electrostatic force of attraction between oppositely charged ions is strong and so requires lots of energy to break.

Ionic bonding

When metal atoms react with non-metal atoms they **transfer** electrons to the non-metal atom.

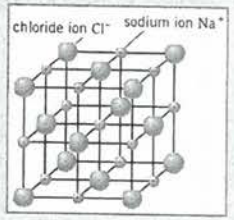




Metal atoms lose electrons to become positive ions. Non-metal atoms gain electrons to become negative ions.

Giant ionic lattice

When metal atoms transfer electrons to non-metal atoms you end up with positive and negative ions. These are attracted to each other by the strong **electrostatic force of attraction**. This is called ionic bonding.

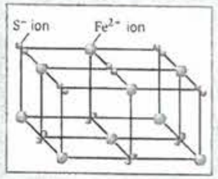


The electrostatic force of attraction works in all directions, so many billions of ions can be bonded together in a 3D structure.

Formulae

The formula of an ionic substance can be worked out

1. from its bonding diagram: for every one magnesium ion there are two fluoride ions – so the formula for magnesium fluoride is MgF_2
2. from a lattice diagram: there are nine Fe^{2+} ions and 18 S^- ions – simplifying this ratio gives a formula of FeS_2



Covalent structures

There are three main types of covalent structure:

Structure and bonding

Giant covalent

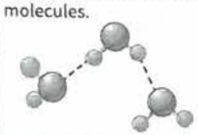
Many billions of atoms, each one with a strong covalent bond to a number of others.

An example of a giant covalent structure is diamond.

Small molecules

Each molecule contains only a few atoms with strong covalent bonds between these atoms. Different molecules are held together by weak **intermolecular forces**.

For example, water is made of small molecules.



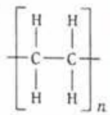
Large molecules

Many repeating units joined by covalent bonds to form a chain.

The small section is bonded to many identical sections to the left and right. The '*n*' represents a large number.

Separate chains are held together by intermolecular forces that are stronger than in small molecules.

Polymers are examples of long molecules.



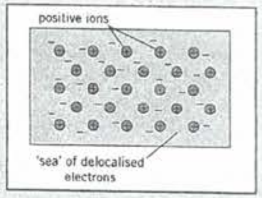
Metals: structure and properties

The atoms that make up metals form layers. The electrons in the outer shells of the atoms are **delocalised** – this means they are free to move through the whole structure.

The positive metal ions are then attracted to these delocalised electrons by the electrostatic force of attraction.

Some important properties of metals are:

- pure metals are **malleable** because the layers can slide over each other
- they are good **conductors** of electricity and of thermal energy because delocalised electrons are free to move through the whole structure
- they have high melting and boiling points because the electrostatic force of attraction between metal ions and delocalised electrons is strong so lots of energy is needed to break it.



Chapter 3: Bonding 2

Knowledge organiser

Properties

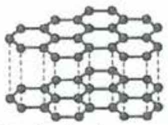
High melting and boiling points because the strong covalent bonds between the atoms must be broken to melt or boil the substances. This requires a lot of energy. Solid at room temperature.	Low melting and boiling points because only the intermolecular forces need to be overcome to melt or boil the substances, not the bonds between the atoms. This does not require a lot of energy as the intermolecular forces are weak. Normally gaseous or liquid at room temperature.	Melting and boiling points are low compared to giant covalent substances but higher than for small molecules. Large molecules have stronger intermolecular forces than small molecules, which require more energy to overcome. Normally solid at room temperature.

Most covalent structures do not conduct electricity because they do not have **delocalised electrons** or ions that are free to move to carry charge.

Graphite

Graphite is a giant covalent structure, but is different to other giant covalent substances.

Structure



Made only of carbon – each carbon atom bonds to three others, and forms hexagonal rings in layers. Each carbon atom has one spare electron, which is delocalised and therefore free to move around the structure.

Hardness

The layers can slide over each other because they are not covalently bonded. Graphite is therefore softer than diamond, even though both are made only of carbon, as each atom in diamond has four strong covalent bonds.

Conductivity

The delocalised electrons are free to move through graphite, so can carry charges and allow an electrical current to flow. Graphite is therefore a conductor of electricity.

Graphene

Graphene consists of only a single layer of graphite. Its strong covalent bonds make it a strong material that can also conduct electricity. It could be used in composites and high-tech electronics.

Fullerenes

- hollow cages of carbon atoms bonded together in one molecule
- can be arranged as a sphere or a tube (called a **nanotube**)
- molecules held together by weak intermolecular forces, so can slide over each other
- conduct electricity

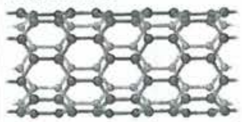
Spheres

Buckminsterfullerene was the first fullerene to be discovered, and has 60 carbon atoms.

Other fullerenes exist with different numbers of carbon atoms arranged in rings that form hollow shapes.

Fullerenes like this can be used as lubricants and in drug delivery.

Nanotubes



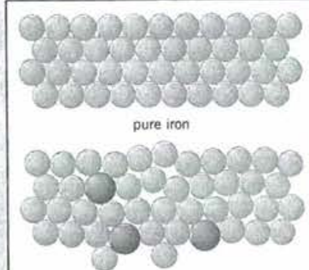
The carbon atoms in nanotubes are arranged in cylindrical tubes.

Their high **tensile strength** (they are difficult to break when pulled) makes them useful in electronics.

Alloys

Pure metals are often too soft to use as they are. Adding atoms of a different element can make the resulting mixture harder because the new atoms will be a different size to the pure metal's atoms. This will disturb the regular arrangement of the layers, preventing them from sliding over each other.

The harder mixture is called an **alloy**.



Measuring particles

We use different units and scales to measure the size of particles.

Particle	Particulate matter	Size	Standard form	Full form
grain of sand	N/A	0.1 mm	1×10^{-4} m	0.0001 m
coarse particles (*e.g.*, dust)	PM_{10}	10 μm	1×10^{-5} m	0.00001 m
fine particles	$PM_{2.5}$	100 nm	1×10^{-7} m	0.0000001 m
nanoparticles	$< PM_{2.5}$	1 to 100 nm	1×10^{-9} to 1×10^{-7} m	0.000000001 m to 0.0000001 m

PM stands for **particulate matter** and is another way of measuring very small particles.

Uses of nanoparticles

Nanoparticles often have very different properties to bulk materials of the same substance, caused by their high surface area-to-volume-ratio.

Nanoparticles have many uses and are an important area of research. They are used in healthcare, electronics, cosmetics, and as catalysts.

However, nanoparticles have the potential to be hazardous to health and to ecosystems, so it is important that they are researched further.

Key terms

Make sure you can write a definition for these key terms.

conductivity, conductor, delocalised electron, electrostatic force of attraction, ion, lattice, layer, malleable, nanoparticle, particulate matter, surface area to volume ratio, transfer

Chapter 3: Bonding

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

#	C3 questions	Answers
1	How are covalent bonds formed?	by atoms sharing electrons
2	Which type of atoms form covalent bonds between them?	non-metals
3	Describe the structure and bonding of a giant covalent substance.	billions of atoms bonded together by strong covalent bonds
4	Describe the structure and bonding of small molecules.	small numbers of atoms group together into molecules with strong covalent bonds between the atoms and weak intermolecular forces between the molecules
5	Describe the structure and bonding of polymers.	many identical molecules joined together by strong covalent bonds in a long chain, with weak intermolecular forces between the chains
6	Why do giant covalent substances have high melting points?	it takes a lot of energy to break the strong covalent bonds between the atoms
7	Why do small molecules have low melting points?	only a small amount of energy is needed to break the weak intermolecular forces
8	Why do large molecules have higher melting and boiling points than small molecules?	the intermolecular forces are stronger in large molecules
9	Why do most covalent substances not conduct electricity?	do not have delocalised electrons or ions
10	Describe the structure and bonding in graphite.	each carbon atom is bonded to three others in hexagonal rings arranged in layers – it has delocalised electrons and weak forces between the layers
11	Why can graphite conduct electricity?	the delocalised electrons can move through the graphite
12	Explain why graphite is soft.	layers are not bonded so can slide over each other
13	What is graphene?	one layer of graphite
14	Give two properties of graphene.	strong, conducts electricity
15	What is a fullerene?	hollow cage of carbon atoms arranged as a sphere or a tube
16	What is a nanotube?	hollow cylinder of carbon atoms
17	Give two properties of nanotubes.	high tensile strength, conduct electricity
18	Give three uses of fullerenes.	lubricants, drug delivery (spheres), high-tech electronics

#	Questions	Answers
19	What is an ion?	atom that has lost or gained electrons
20	Which kinds of elements form ionic bonds?	metals and non-metals
21	What charges do ions from Groups 1 and 2 form?	Group 1 forms 1+, Group 2 forms 2+
22	What charges do ions from Groups 6 and 7 form?	Group 6 forms 2–, Group 7 forms 1–
23	Name the force that holds oppositely charged ions together.	electrostatic force of attraction
24	Describe the structure of a giant ionic lattice.	regular structure of alternating positive and negative ions, held together by the electrostatic force of attraction
25	Why do ionic substances have high melting points?	electrostatic force of attraction between positive and negative ions is strong and requires lots of energy to break
26	Why don't ionic substances conduct electricity when solid?	ions are fixed in position so cannot move, and there are no delocalised electrons
27	When can ionic substances conduct electricity?	when melted or dissolved
28	Why do ionic substances conduct electricity when melted or dissolved?	ions are free to move and carry charge
29	Describe the structure of a pure metal.	layers of positive metal ions surrounded by delocalised electrons
30	Describe the bonding in a pure metal.	strong electrostatic forces of attraction between metal ions and delocalised electrons
31	What are four properties of pure metals?	malleable, high melting/boiling points, good conductors of electricity, good conductors of thermal energy
32	Explain why pure metals are malleable.	layers can slide over each other easily
33	Explain why metals have high melting and boiling points.	electrostatic force of attraction between positive metal ions and delocalised electrons is strong and requires a lot of energy to break
34	Why are metals good conductors of electricity and of thermal energy?	delocalised electrons are free to move through the metal
35	What is an alloy?	mixture of a metal with atoms of another element
36	Explain why alloys are harder than pure metals.	different sized atoms disturb the layers, preventing them from sliding over each other
37	How big are nanoparticles?	1–100 nm
38	How are nanomaterials different from bulk materials?	nanomaterials have a much higher surface area-to-volume ratio
39	What is the relationship between side length and surface area-to-volume ratio?	as side length decreases by a factor of ten, the surface-area-to-volume ratio increases by a factor of ten
40	What are nanoparticles used for?	used in healthcare, electronics, cosmetics, and catalysts

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Chapter 4: Calculations

Knowledge organiser

Formula mass

Every substance has a **formula mass**, M_r.

formula mass M_r = *sum (relative atomic mass of all the atoms in the formula)*

Avogadro's constant (HT only)

One mole of a substance contains 6.02×10^{23} atoms, ions, or molecules. This is **Avogadro's constant**.

One mole of a substance has the same mass as the M_r of the substance. For example, the M_r (H_2O) = 18, so 18 g of water molecules contains 6.02×10^{23} molecules, and is called one mole of water.

You can write this as: $\text{moles} = \frac{\text{mass}}{M_r}$

Theoretical yield

The **theoretical yield** of a chemical reaction is the mass of a product that you expect to be produced.

Even though no atoms are gained or lost during a chemical reaction, it is not always possible to obtain the theoretical yield because

- some of the product can be lost when it is separated from the reaction mixture
- there can be unexpected side reactions between reactants that produce different products
- the reaction may be reversible.

Percentage yield

The **yield** is the amount of product that you actually get in a chemical reaction.

Percentage yield is the actual yield as a proportion of the theoretical yield:

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Atom economy

The **atom economy** of a reaction tells you the proportion of atoms that you started with that are part of *useful* products.

High atom economies are more sustainable, as they mean fewer atoms are being wasted in products that are not useful.

The percentage atom economy is calculated by:

$$\text{atom economy} = \frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100$$

Key terms

Make sure you can write a definition for these key terms.

atom economy, burette, concordant, end point, excess reactant, formula mass, limiting reactant, percentage yield, pipette, room temperature and pressure, theoretical yield, titration, titre, useful, yield

Using balanced equations (HT only)

In a balanced symbol equation the sum of the M_r of the reactants equals the sum of the M_r of the products.

If you are asked what mass of a product will be formed from a given mass of a specific reactant, you can use the steps below to calculate the result.

1. balance the symbol equation
2. calculate moles of the substance with a known mass using $\text{moles} = \frac{\text{mass}}{M_r}$
3. using the balanced symbol equation, work out the number of moles of the unknown substance
4. calculate the mass of the unknown substance using mass = moles × M_r

If you are asked to balance an equation, you can use the steps below to work out the answer.

1. work out M_r of all the substances
2. calculate the number of moles of each substance in the reaction using $\text{moles} = \frac{\text{mass}}{M_r}$
3. convert to a whole number ratio
4. balance the symbol equation

Concentration

Concentration is the amount of solute in a volume of solvent.

The unit of concentration is g/dm³. Concentration can be calculated using:

$$\text{concentration (g/dm}^3) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$$

Sometimes volume is measured in cm³:

$$\text{volume (dm}^3) = \frac{\text{volume (cm}^3)}{1000}$$

- lots of solute in little solution = high concentration
- little solute in lots of solution = low concentration

Concentration in mol/dm³

Concentration can also be measured in mol/dm³.

$$\text{concentration of solution (mol/dm}^3) = \frac{\text{number of moles of solute}}{\text{volume of solution (dm}^3)}$$

You can use this formula and mass = moles × M_r to calculate the mass of solute dissolved in a solution.

- The greater the mass of solute in solution, the greater the number of moles of solute, and therefore the greater the concentration.
- If the same number moles of solute is dissolved in a smaller volume of solution, the concentration will be greater.

mol is a the unit of moles

Excess and limiting reactants (HT only)

In a chemical reaction between two or more reactants, often one of the reactants will run out before the others. You then have some of the other reactants left over. The reactant that is left over is in **excess**. The reactant that runs out is the **limiting reactant**.

To work out which reactants are in excess and which is the limiting reactant, you need to:

1. write the balanced symbol equation for the reaction
2. pick one of the reactants and its quantity as given in the question
3. use the ratio of the reactants in the balanced equation to see how much of the other reactant you need
4. compare this value to the quantity given in the question
5. determine which reactant is in excess and which is limiting.

Moles of gases (HT only)

At any given temperature and pressure, the same number of moles of a gas will occupy the same volume.

At room temperature (25 °C) and pressure (1 atm), one mole of *any* gas will occupy 24 dm³.

To calculate the number of moles of a gas:

$$\text{moles of a gas} = \frac{\text{volume (dm}^3)}{24\text{ dm}^3}$$

or

$$\text{moles of a gas} = \frac{\text{volume (cm}^3)}{24\,000\text{ cm}^3}$$

Calculating concentration

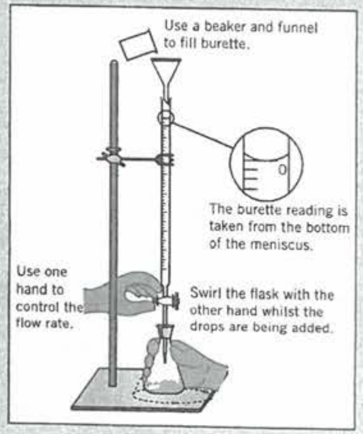
To calculate the concentration of the unknown solution (the solution in the conical flask):

1. Write a balanced symbol equation for the reaction.
2. Calculate the moles used from the known solution using:
   $\text{moles} = \text{concentration (mol/dm}^3) \times \text{volume (dm}^3)$
3. Use the ratio from the balanced symbol equation to deduce the number of moles present in the unknown solution.
4. Calculate the concentration of the unknown solution using:
   $\text{concentration (mol/dm}^3) = \frac{\text{moles}}{\text{volume (dm}^3)}$

Titration

Titration is an experimental technique to work out the concentration of an unknown solution in the reaction between an acid and an alkali.

1. Use a pipette to extract a known volume of the solution with an unknown concentration. A pipette measures a fixed volume only.
2. Add the solution of unknown concentration to a conical flask and put the conical flask on a white tile.
3. Add a few drops of a suitable indicator to the conical flask.
4. Add the other solution with a known concentration to the burette.
5. Carry out a rough titration to find out approximately what volume of solution in the burette needs to be added to the solution in the conical flask. Add the solution from the burette to the solution in the conical flask 1 cm³ at a time until the end point is reached.
6. The end point is when the indicator just changes colour.
7. Record the volume of the end point as your rough value.
8. Now repeat steps 1–7, but as you approach the end point add the solution from the burette drop-by-drop. Swirl the conical flask in between drops.
9. Record the volume of the end point.



Chapter 4: Calculations

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C4 questions	Answers
1	What is a mole?	mass of a substance that contains 6.02×10^{23} particles
2	Give the value for Avogadro's constant.	6.02×10^{23}
3	Which formula is used to calculate the number of moles from mass and M_r?	moles = $\frac{\text{mass}}{M_r}$
4	Which formula is used to calculate the mass of a substance from number of moles and M_r?	mass = moles × M_r
5	What is a limiting reactant?	the reactant that is completely used up in a chemical reaction
6	What is a unit for concentration?	g/dm³ or mol/dm³
7	Which formula is used to calculate concentration from mass and volume?	$\text{concentration (g/dm}^3) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$
8	Which formula is used to calculate volume from concentration and mass?	$\text{volume (dm}^3) = \frac{\text{mass (g)}}{\text{concentration (g/dm}^3)}$
9	Which formula is used to calculate mass from concentration in g/dm³ and volume?	mass (g) = concentration (g/dm³) × volume (dm³)
10	How can you convert a volume reading in cm³ to dm³?	divide by 1000
11	If the amount of solute in a solution is increased, what happens to its concentration?	increases
12	If the volume of water in a solution is increased, what happens to its concentration?	decreases
13	What is the yield of a reaction?	mass of product obtained from the reaction
14	What is the theoretical yield of a reaction?	maximum mass of the product that could have been produced
15	Why is the actual yield always less than the theoretical yield?	• reaction may be reversible • some of the product can be lost on separation • unexpected side reactions between reactants
16	What is the percentage yield?	actual yield as a proportion of theoretical yield
17	How is percentage yield calculated?	$\frac{\text{actual yield}}{\text{theoretical yield}} \times 100$
18	What is atom economy?	measure of how many atoms of the reactants end up as useful products
19	Why is a high atom economy desirable?	results in less waste/is more sustainable
20	How is percentage atom economy calculated?	$\frac{M_r \text{ of useful product}}{M_r \text{ of all products}} \times 100$
21	How can concentration in mol/dm³ be calculated?	$\frac{\text{moles of solute}}{\text{volume (dm}^3)}$
22	What is a titration?	method used to calculate the concentration of an unknown solution
23	What is the end-point?	the point at which the reaction is complete (when the indicator changes colour) and no substance is in excess
24	How should solution be added from the burette close to the end point?	drop by drop, swirling in between
25	Why is a white tile used in titration?	to see the colour change better
26	What is a titre?	volume of solution added from the burette
27	What volume does one mole of any gas occupy at room temperature and pressure?	24 dm³ or 24 000 cm³

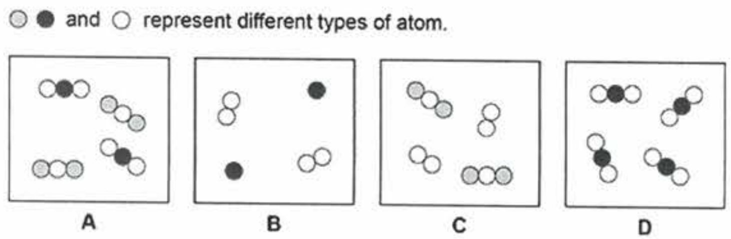
Put paper here

Q1.

This question is about elements, compounds and mixtures.

Figure 1 shows diagrams which represent the atoms and molecules in different substances.

Figure 1



(a) Which diagram in **Figure 1** represents a pure compound?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐

(1)

(b) Which diagram in **Figure 1** represents a mixture of an element and a compound?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐

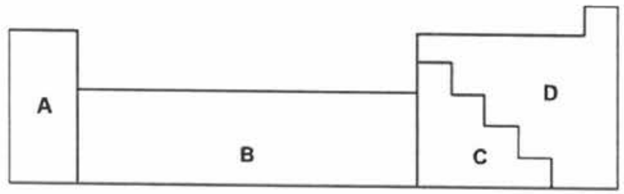
(1)

(c) Elements are metals or non-metals.

Figure 2 shows an outline of the periodic table.

The periodic table is divided into sections.

Figure 2



Where are metals found in the periodic table?

Tick (✓) **one** box.

Section **A** only	☐
Sections **A**, **B** and **C**	☐
Sections **B**, **C** and **D**	☐
Section **D** only	☐

(1)

(d) Which **two** of the following are typical properties of a transition metal?

Tick (✓) **two** boxes.

Can be bent and shaped	☐
Good conductor of electricity	☐
Low density	☐
Low melting point	☐
Poor conductor of heat	☐

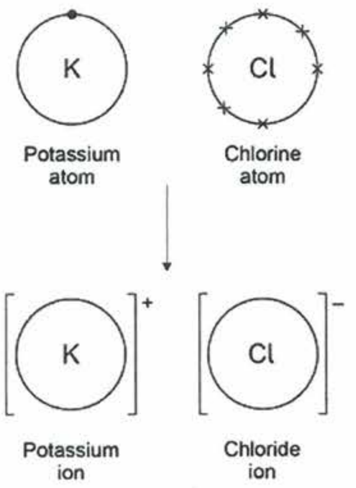
(2)

(e) Potassium and chlorine react to produce potassium chloride.

An atom of potassium loses an electron to form a potassium ion.

An atom of chlorine gains an electron to form a chloride ion.

Complete the dot and cross diagram.

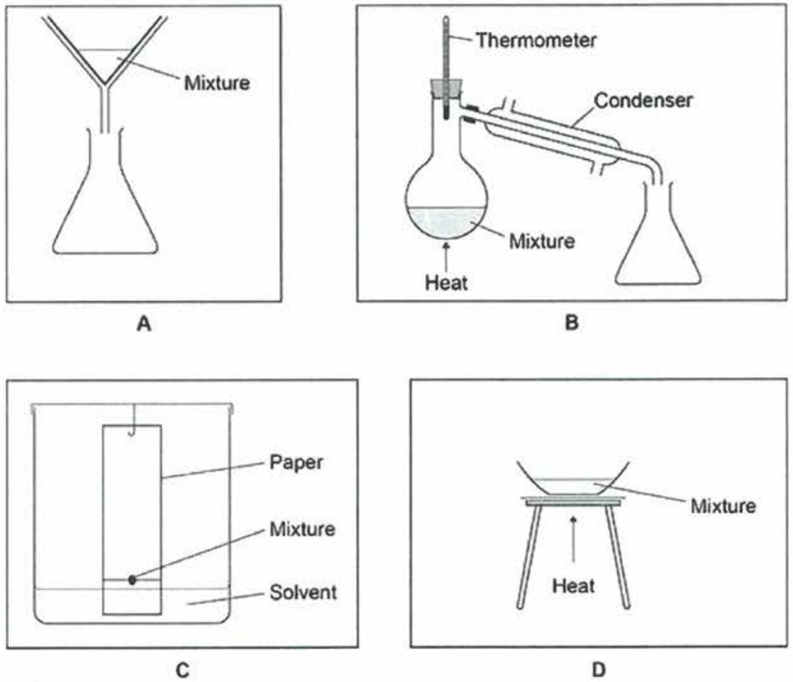


(2)

Mixtures are separated by different methods.

Figure 3 shows the apparatus for separating four different types of mixture.

Figure 3



(f) Which apparatus could be used to collect water from sodium chloride solution?

Use **Figure 3**.

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(g) Which apparatus shows filtration?

Use **Figure 3**.

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)
(Total 9 marks)

Q2.

This question is about carbon and carbon compounds.

An atom of carbon is represented as:

(Mass number) 13
(Atomic number) 6 $^{13}_{6}C$

(a) What is the number of protons in this atom of carbon?

Tick (✓) **one** box.

1 ☐ 6 ☐ 7 ☐ 13 ☐

(1)

(b) What is the number of neutrons in this atom of carbon?

Tick (✓) **one** box.

1 ☐ 6 ☐ 7 ☐ 13 ☐

(1)

(c) What is the number of electrons in this atom of carbon?

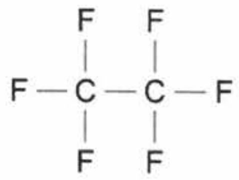
Tick (✓) **one** box.

1 ☐ 6 ☐ 7 ☐ 13 ☐

(1)

(d) **Figure 1** shows the structure of a carbon compound.

Figure 1



Complete the formula of the carbon compound.

C__F__

(1)

(e) Methane:

- is a carbon compound
- exists as small molecules
- has a low boiling point.

What is the reason for the low boiling point of methane?

Tick (✓) **one** box.

Covalent bonds **and** intermolecular forces are weak. ☐

Only covalent bonds are weak. ☐

Only intermolecular forces are weak. ☐

(1)

(f) Buckminsterfullerene (C_{60}) is a form of carbon.

Buckminsterfullerene was the first fullerene to be discovered.

What is the shape of a buckminsterfullerene molecule?

Tick (✓) **one** box.

Cubic ☐

Cylindrical ☐

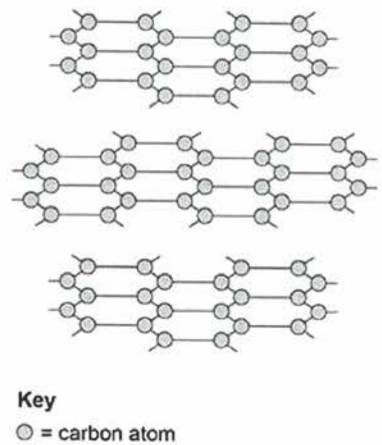
Spherical ☐

(1)

(g) Graphite is a form of carbon.

Figure 2 represents the structure of graphite.

Figure 2



How many covalent bonds does each carbon atom form in graphite?

Tick (✓) **one** box.

1 ☐

2 ☐

3 ☐

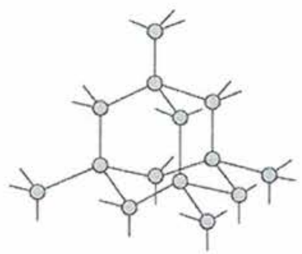
4 ☐

(1)

(h) Diamond is another form of carbon.

Figure 3 represents the structure of diamond.

Figure 3



Key

○ = carbon atom

Describe the structure and bonding in diamond.

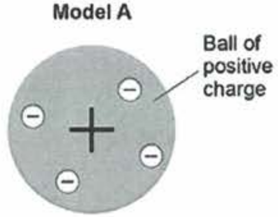
(3)

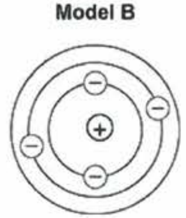
(Total 10 marks)

Q3.

This question is about models of the atom.

The figure below shows two early models of the atom.





(a) Name the models of the atom shown in above figure.

Model **A** ______________________

Model **B** ______________________

(2)

(b) Compare model **A** with the model of the atom used today.

Use the figure above.

(4)

(c) Chadwick's experiments showed the existence of neutrons in an atom.

This led to an understanding of isotopes.

Define the term 'isotopes'.

Refer to subatomic particles in your answer.

(2)

(Total 8 marks)

Q4.

This question is about ionic compounds and electrolysis.

Calcium chloride is an ionic compound.

(a) Calcium and chlorine react to produce calcium chloride.

Describe what happens to calcium atoms and chlorine atoms when the ionic compound calcium chloride is formed.

(4)

(b) Solid calcium chloride **cannot** be electrolysed.

Give **one** reason why.

(1)

(c) Name the product formed at the negative electrode when aqueous calcium chloride solution is electrolysed.

(1)

(d) What is the half equation for the reaction at the positive electrode when aqueous calcium chloride solution is electrolysed?

Tick (✓) **one** box.

$2\ Cl^- \rightarrow Cl_2 + 2\ e^-$ ☐

$Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$ ☐

$4\ OH^- \rightarrow O_2 + 2\ H_2O + 4\ e^-$ ☐

$O_2 + 2\ H_2O + 4\ e^- \rightarrow 4\ OH^-$ ☐

(1)

(e) A student investigated the electrolysis of green copper chromate solution.

Figure 1 shows the apparatus.

Figure 1

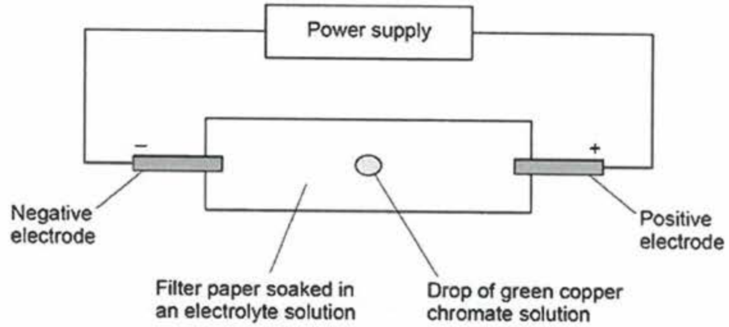
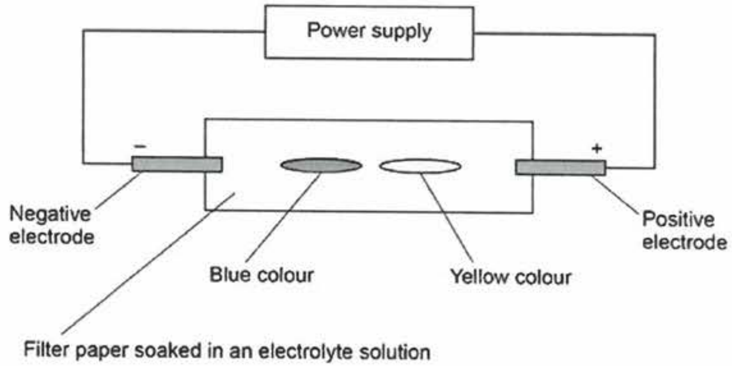


Figure 2 shows the results.

Figure 2



Copper chromate solution contains the ions Cu^{2+} and CrO_4^{2-}

Explain the results shown in **Figure 2**.

(3)
(Total 10 marks)

Q5.

This question is about iron.

(a) Iron is a metal.

Describe how iron conducts thermal energy.

____

____

____

____

(2)

(b) Pure iron is too soft for many uses.

Explain why mixing iron with other metals makes alloys which are harder than pure iron.

____

____

____

____

____

____

(3)

(c) When iron reacts with chlorine, 0.12 mol of iron reacts with 0.18 mol of chlorine (Cl_2).

Which is the correct equation for the reaction?

Tick (✓) **one** box.

$Fe + Cl_2 \rightarrow FeCl_2$ ☐

$Fe + 3\ Cl_2 \rightarrow FeCl_6$ ☐

$2\ Fe + Cl_2 \rightarrow 2\ FeCl$ ☐

$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$ ☐

(1)

The most common oxides of iron are Fe_2O_3 and Fe_3O_4

(d) What is the ratio of the numbers of ions in Fe_3O_4?

Tick (✓) **one** box.

$2\ Fe^{2+} : 1\ Fe^{3+} : 4\ O^{2-}$ ☐

$1\ Fe^{2+} : 2\ Fe^{3+} : 4\ O^{2-}$ ☐

$3\ Fe^{2+} : 4\ O^{2-}$ ☐

$3\ Fe^{3+} : 4\ O^{2-}$ ☐

(1)

(e) Calculate the percentage (%) by mass of iron in Fe_3O_4

Relative atomic masses (A_r): O = 16 Fe = 56

____

____

____

____

____

Percentage by mass of iron = __________ %

(3)

(f) Fe_2O_3 reacts with carbon to produce carbon dioxide.

The equation for the reaction is:

$$2\ Fe_2O_3(s) + 3\ C(s) \rightarrow 4\ Fe(s) + 3\ CO_2(g)$$

Calculate the volume of carbon dioxide gas at room temperature and pressure that is produced from 40.0 kg of Fe_2O_3 using excess carbon.

Relative formula mass (M_r): $Fe_2O_3 = 160$

The volume of 1 mole of any gas at room temperature and pressure is 24 dm^3.

____

____

____

____

____

____

____

Volume of carbon dioxide = ____________ dm^3

(5)
(Total 15 marks)

Q6.

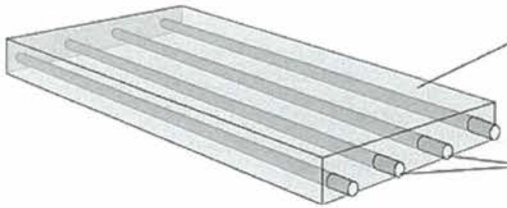
This question is about materials.

Pre-stressed concrete is a composite material.

The concrete is strengthened using high carbon steel bars.

Figure 1 shows the structure of a piece of pre-stressed concrete.

Figure 1



(a) Which **two** words describe the high carbon steel bars?

Tick (✓) **two** boxes.

Alloy ☐

Binder ☐

Matrix ☐

Ore ☐

Reinforcement ☐

(2)

Limestone is mainly calcium carbonate.

Limestone is a raw material used in the production of concrete.

(b) In the first part of the production of concrete:

- air is heated by burning methane

- the hot air is used to heat limestone
- the limestone decomposes.

The equation for the decomposition of limestone is:

calcium carbonate → calcium oxide + carbon dioxide

Give **two** ways in which a greenhouse gas is released in this process.

1 ____

____

2 ____

____

(2)

(c) How could a sample of limestone be tested to show the presence of carbonate ions?

Complete the sentences.

Choose answers from the box.

barium chloride	**hydrochloric acid**	**limewater**
sodium hydroxide	**universal indicator**	

The substance added to the limestone is ____________.

The gas produced is identified using ____________.

(2)

The table below gives some information about plain concrete and pre-stressed concrete.

	Plain concrete	**Pre-stressed concrete**
Cost in £ per m^3	75	225
Density in kg per m^3	2300	2500
Strength in arbitrary units	600	3000

(d) Explain why pre-stressed concrete rather than plain concrete is used to make bridges that carry heavy lorries.

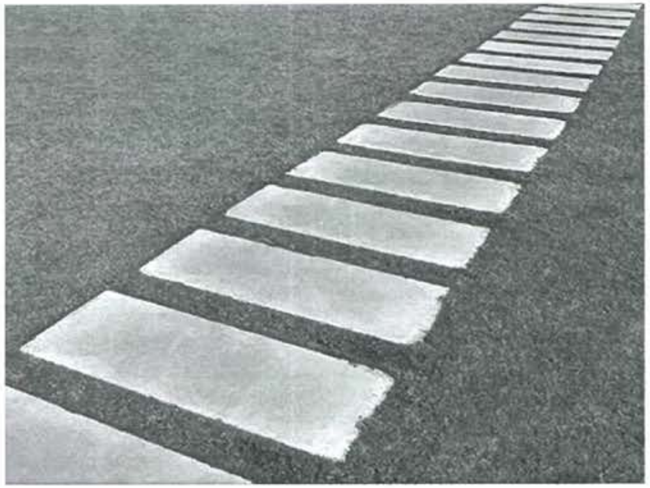
Use the table above.

____

(2)

(e) **Figure 2** shows a garden path made of plain concrete slabs.

Figure 2



Suggest **two** reasons why plain concrete rather than pre-stressed concrete is used to make slabs for garden paths.

Use the table above.

1 ______________________________

____

2 ______________________________

____

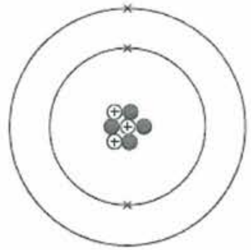
(2)

(Total 10 marks)

Q7.

This question is about atomic structure.

The figure below represents the structure of a lithium atom.



(a) Name the particle in the atom that has a positive charge.

____

(1)

(b) Name the particle in the atom that has the smallest mass.

____

(1)

(c) Complete the sentences.

Choose the answers from the box.

3	**4**	**7**	**10**

The mass number of the lithium atom is ______________.

The number of neutrons in the lithium atom is ______________.

(2)

(d) What are lithium atoms with different numbers of neutrons called?

Tick (✓) **one** box.

Compounds ☐

Ions ☐

Isotopes ☐

Molecules ☐

(1)

(e) Name the particle in the atom discovered by James Chadwick.

______________________________.

(1)

(f) An element has two isotopes.

The table shows information about the isotopes.

	Mass number	Percentage (%) abundance
Isotope 1	10	20
Isotope 2	11	80

Calculate the relative atomic mass (A_r) of the element.

Use the equation:

$$A_r = \frac{(\text{mass number} \times \text{percentage}) \text{ of isotope 1} + (\text{mass number} \times \text{percentage}) \text{ of isotope 2}}{100}$$

Give your answer to 1 decimal place.

___

Relative atomic mass (A_r) = ___

(2)

(g) The radius of an atom is 0.2 nm

The radius of the nucleus is $\frac{1}{10000}$ the radius of the atom.

Calculate the radius of the nucleus.

Give your answer in standard form.

___

Radius = ___ nm

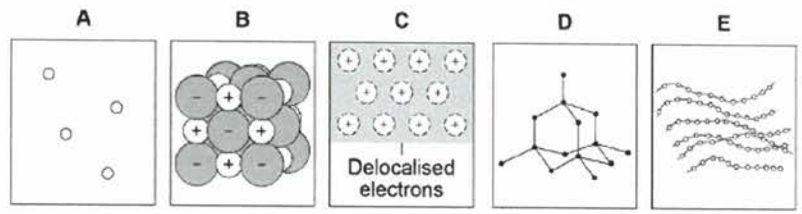
(2)

(Total 10 marks)

Q8.

Figure 1 shows the structure of five substances.

Figure 1



(a) Which diagram shows a gas?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(b) Which diagram shows the structure of diamond?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(c) Which diagram shows a metallic structure?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(d) Which diagram shows a polymer?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(e) A chlorine atom has 7 electrons in the outer shell.

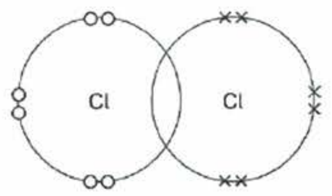
Two chlorine atoms covalently bond to form a chlorine molecule, Cl_2

Figure 2 is a dot and cross diagram showing the outer shells and some electrons in a chlorine molecule.

Complete the dot and cross diagram.

Show only the electrons in the outer shell.

Figure 2



(1)

(f) What is the reason for chlorine's low boiling point?

Tick (✓) **one** box.

Strong covalent bonds ☐

Strong forces between molecules ☐

Weak covalent bonds ☐

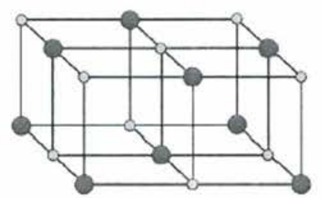
Weak forces between molecules ☐

(1)

Figure 3 represents the structure of manganese oxide.

Manganese oxide is an ionic compound.

Figure 3



(g) Determine the empirical formula of manganese oxide.

Use **Figure 3**.

___

___

Empirical formula = ___

(1)

(h) Why does manganese oxide conduct electricity as a liquid?

Tick (✓) **one** box.

Atoms move around in the liquid ☐

Electrons move around in the liquid ☐

Ions move around in the liquid ☐

Molecules move around in the liquid ☐

(1)

(Total 8 marks)

Q9.

An atom of aluminium has the symbol $^{27}_{13}Al$

(a) Give the number of protons, neutrons and electrons in this atom of aluminium.

Number of protons ___

Number of neutrons ___

Number of electrons ___

(3)

(b) Why is aluminium positioned in Group 3 of the periodic table?

___

___

(1)

(c) In the periodic table, the transition elements and Group 1 elements are metals.

Some of the properties of two transition elements and two Group 1 elements are shown in the table below.

	Transition elements		Group 1 elements	
	Chromium	Iron	Sodium	Caesium
Melting point in °C	1857	1535	98	29
Formula of	CrO Cr_2O_3	FeO Fe_2O_3	Na_2O	Cs_2O

oxides	CrO_2 CrO_3	Fe_3O_4		

Use your own knowledge **and** the data in the table above to compare the chemical and physical properties of transition elements and Group 1 elements.

(6)

(Total 10 marks)

Q10.

This question is about different substances and their structures.

(a) Draw **one** line from each statement to the diagram which shows the structure.

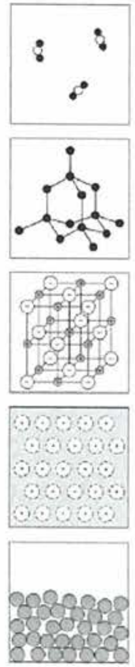
Statement **Structure**

The substance is a gas

The substance is a liquid

The substance is ionic

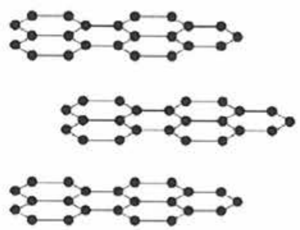
The substance is a solid metal



(4)

(b) **Figure 1** shows the structure of an element.

Figure 1



What is the name of this element?

Tick **one** box.

Carbon ☐

Chloride ☐

Nitrogen ☐

Xenon ☐

(1)

(c) Why does this element conduct electricity?

Tick **one** box.

It has delocalised electrons ☐

It contains hexagonal rings ☐

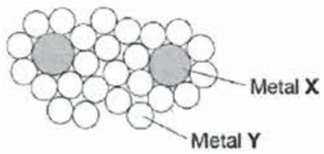
It has weak forces between the layers ☐

It has ionic bonds ☐

(1)

(d) **Figure 2** shows the structure of an alloy.

Figure 2



Explain why this alloy is harder than the pure metal **Y**.

(2)

(e) What percentage of the atoms in the alloys are atoms of **X**?

(2)

(f) What type of substance is an alloy?

Tick **one** box.

Compound ☐

Element ☐

Mixture ☐

(1)

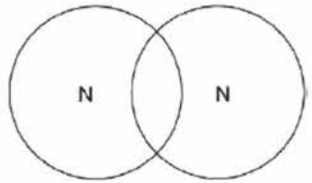
(Total 11 marks)

Q11.

This question is about structure and bonding.

(a) Complete the dot and cross diagram to show the covalent bonding in a nitrogen molecule, N_2

Show only the electrons in the outer shell.



(2)

(b) Explain why nitrogen is a gas at room temperature.

Answer in terms of nitrogen's structure.

(3)

(c) Graphite and fullerenes are forms of carbon.

Graphite is soft and is a good conductor of electricity.

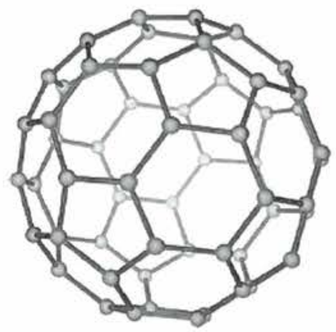
Explain why graphite has these properties.

Answer in terms of structure and bonding.

(4)

(d) **Figure 1** shows a model of a Buckminsterfullerene molecule.

Figure 1



A lubricant is a substance that allows materials to move over each other easily.

Suggest why Buckminsterfullerene is a good lubricant.

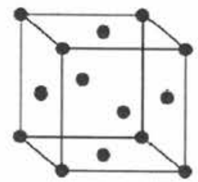
Use **Figure 1**.

(2)

Silver can form cubic nanocrystals.

Figure 2 represents a silver nanocrystal.

Figure 2



(e) A silver nanocrystal is a cube of side 20 nm

Calculate the surface area to volume ratio of the nanocrystal.

Surface area to volume ratio = ____________

(3)

(f) Silver nanoparticles are sometimes used in socks to prevent foot odour.

Suggest why it is cheaper to use nanoparticles of silver rather than coarse particles of silver.

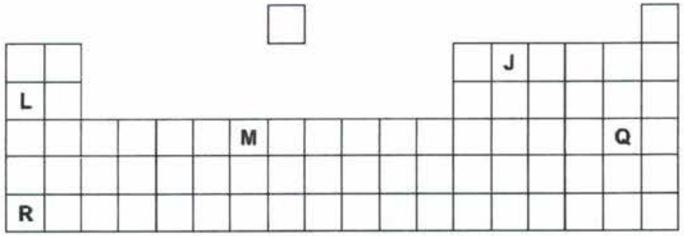
(2)

(Total 16 marks)

Q12.

Figure 1 shows an outline of the modern periodic table.

Figure 1



J, **L**, **M**, **Q** and **R** represent elements in the periodic table.

(a) Which element has four electrons in its outer shell?

Tick (✓) **one** box.

J ☐ L ☐ M ☐ Q ☐ R ☐

(1)

(b) Which **two** elements in **Figure 1** are in the same period?

________________ and ________________

(1)

(c) Which element reacts with potassium to form an ionic compound?

Tick (✓) **one** box.

J ☐ L ☐ M ☐ Q ☐ R ☐

(1)

(d) Which element forms ions with different charges?

Tick (✓) **one** box.

J ☐ L ☐ M ☐ Q ☐ R ☐

(1)

(e) Which element has three electron shells?

Tick (✓) **one** box.

J ☐ L ☐ M ☐ Q ☐ R ☐

(1)

(f) In the 1860s scientists were trying to organise elements.

Figure 2 shows the table published by John Newlands in 1865.

The elements are arranged in order of their atomic weights.

Figure 2

H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co,Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce,La	Zr	Di,Mo	Ro,Ru
Pd	Ag	Cd	U	Sn	Sb	Te

Figure 3 shows the periodic table published by Dmitri Mendeleev in 1869.

Figure 3

H							
Li	Be	B	C	N	O	F	
Na	Mg	Al	Si	P	S	Cl	
K Cu	Ca Zn	? ?	Ti ?	V As	Cr Se	Mn Br	Fe Co Ni
Rb Ag	Sr Cd	Y In	Zr Sn	Nb Sb	Mo Te	? I	Ru Rh Pd

Mendeleev's table became accepted by other scientists whereas Newlands' table was not.

Evaluate Newlands' and Mendeleev's tables.

You should include:

- a comparison of the tables
- reasons why Mendeleev's table was more acceptable.

Use **Figure 2** and **Figure 3** and your own knowledge.

(6)

(Total 11 marks)

Q13.

This question is about atoms.

(a) What does the number 19 represent in $^{19}_{9}F$?

____

(1)

(b) How many atoms are present in one mole of fluorine atoms?

Tick (✓) **one** box.

2.03×10^{26} ☐

2.06×10^{23} ☐

6.02×10^{23} ☐

6.02×10^{26} ☐

(1)

(c) The plum pudding model of the atom was replaced by the nuclear model.

The nuclear model was developed after the alpha particle scattering experiment.

Compare the plum pudding model with the nuclear model of the atom.

____

____

____

____

____

____

____

____

(4)

(d) An element has three isotopes.

The table shows the mass numbers and percentage of each isotope.

	Isotope 1	Isotope 2	Isotope 3
Mass number	24	25	26
Percentage (%)	78.6	10.1	11.3

Calculate the relative atomic mass (A_r) of the element.

Give your answer to 3 significant figures.

____

____

____

____

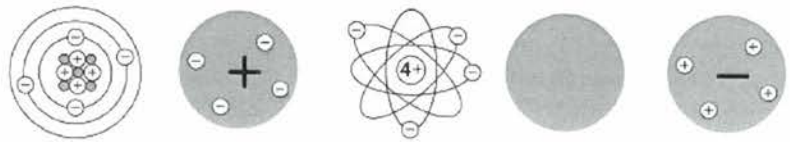
Relative atomic mass = ______________

(2)

(Total 8 marks)

Q14.

The diagram below represents different models of the atom.



A B C D E

(a) Which diagram shows the plum pudding model of the atom?

Tick **one** box.

A	☐	B	☐	C	☐	D	☐	E	☐

(1)

(b) Which diagram shows the model of the atom developed from the alpha particle scattering experiment?

Tick **one** box.

A	☐	B	☐	C	☐	D	☐	E	☐

(1)

(c) Which diagram shows the model of the atom resulting from Bohr's work?

Tick **one** box.

A	☐	B	☐	C	☐	D	☐	E	☐

(1)

(d) Define the mass number of an atom.

____

____

(1)

(e) Element **X** has two isotopes. Their mass numbers are 69 and 71

The percentage abundance of each isotope is:

- 60% of ^{69}**X**
- 40% of ^{71}**X**

Estimate the relative atomic mass of element **X**.

Tick **one** box.

< 69.5 ☐

Between 69.5 and 70.0 ☐

Between 70.0 and 70.5 ☐

> 70.5 ☐

(1)

(f) Chadwick's experimental work on the atom led to a better understanding of isotopes.

Explain how his work led to this understanding.

____

____

____

____

____

____

(3)
(Total 8 marks)

Q15.

This question is about the structure of the atom.

(a) Complete the sentences.

Choose answers from the box.

Each word may be used once, more than once, or not at all.

electron	ion	neutron	nucleus	proton

The centre of the atom is the ____________.

The two types of particle in the centre of the atom are the proton and the ____________.

James Chadwick proved the existence of the ____________.

Niels Bohr suggested particles orbit the centre of the atom. This type of particle is the ____________.

The two types of particle with the same mass are the neutron and the ____________.

(5)

The table below shows information about two isotopes of element **X**.

	Mass number	Percentage (%) abundance
Isotope 1	63	70
Isotope 2	65	30

(b) Calculate the relative atomic mass (A_r) of element **X** using the equation:

$$A_r = \frac{(\text{mass number} \times \text{percentage})\text{ of isotope 1} + (\text{mass number} \times \text{percentage})\text{ of isotope 2}}{100}$$

Use the table above.

Give your answer to 1 decimal place.

____

____

____

____

A_r = ____________

(2)

(c) Suggest the identity of element **X**.

Use the periodic table.

Element **X** is ______________________________

(1)

(d) The radius of an atom of element **X** is 1.2×10^{-10} m

The radius of the centre of the atom is $\frac{1}{10000}$ the radius of the atom.

Calculate the radius of the centre of an atom of element **X**.

Give your answer in standard form.

Radius = ____________ m

(2)

(Total 10 marks)

Q16.

This question is about atomic structure.

(a) Atoms contain subatomic particles.

The table below shows properties of two subatomic particles.

Complete the table.

Name of particle	Relative mass	Relative charge
neutron		
		+1

(2)

An element **X** has two isotopes.

The isotopes have different mass numbers.

(b) Define mass number.

(1)

(c) Why is the mass number different in the two isotopes?

(1)

(d) The model of the atom changed as new evidence was discovered.

The plum pudding model suggested that the atom was a ball of positive charge with

electrons embedded in it.

Evidence from the alpha particle scattering experiment led to a change in the model of the atom from the plum pudding model.

Explain how.

(4)

(Total 8 marks)

Q17.

This question is about the periodic table.

In the 19th century, some scientists tried to classify the elements by arranging them in order of their atomic weights.

The figure below shows the periodic table Mendeleev produced in 1869.

His periodic table was more widely accepted than previous versions.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Period 1	H						
Period 2	Li	Be	B	C	N	O	F
Period 3	Na	Mg	Al	Si	P	S	Cl
Period 4	K Cu	Ca Zn	* *	Ti *	V As	Cr Se	Mn Br
Period 5	Rb Ag	Sr Cd	Y In	Zr Sn	Nb Sb	Mo Te	* I

(a) The atomic weight of tellurium (Te) is 128 and that of iodine (I) is 127

Why did Mendeleev reverse the order of these two elements?

(1)

(b) Mendeleev left spaces marked with an asterisk *

He left these spaces because he thought missing elements belonged there.

Why did Mendeleev's periodic table become more widely accepted than previous versions?

(3)

(c) Mendeleev arranged the elements in order of their atomic weight.

What is the modern name for atomic weight?

Tick (✓) **one** box.

- Atomic number ☐
- Mass number ☐
- Relative atomic mass ☐
- Relative formula mass ☐

(1)

(d) Complete the sentence.

In the modern periodic table, the elements are arranged in order of

____

(1)

Chlorine, iodine and astatine are in Group 7 of the modern periodic table.

(e) Astatine (At) is below iodine in Group 7.

Predict:

- the formula of an astatine molecule
- the state of astatine at room temperature.

Formula of astatine molecule ______________________________

State at room temperature ______________________________

(2)

(f) Sodium is in Group 1 of the modern periodic table.

Describe what you would see when sodium reacts with chlorine.

(2)

(Total 10 marks)

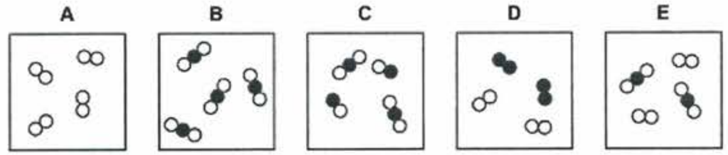
Q18.

This question is about elements, compounds and mixtures.

Figure 1 shows five different substances, **A**, **B**, **C**, **D** and **E**.

○ and ● represent atoms of different elements.

Figure 1



Use **Figure 1** to answer parts (a) to (c)

(a) Which substance is only one compound?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(b) Which substance is a mixture of elements?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

(c) Which substance is a mixture of an element and a compound?

Tick (✓) **one** box.

A ☐ B ☐ C ☐ D ☐ E ☐

(1)

Substances are separated from a mixture using different methods.

(d) Draw **one** line from each method of separation to the substance and mixture it would separate.

Method of separation	**Substance and mixture**
	blue food colour from a mixture of food colours
chromatography	copper from an alloy of copper and zinc
	copper sulfate from copper sulfate solution
crystallisation	ethanol from a mixture of ethanol and water

(2)

(e) Sand does not dissolve in water. A student separates a mixture of sand and water by filtration.

Draw a diagram of the apparatus the student could use.

You should label:

- where the sand is collected
- where the water is collected.

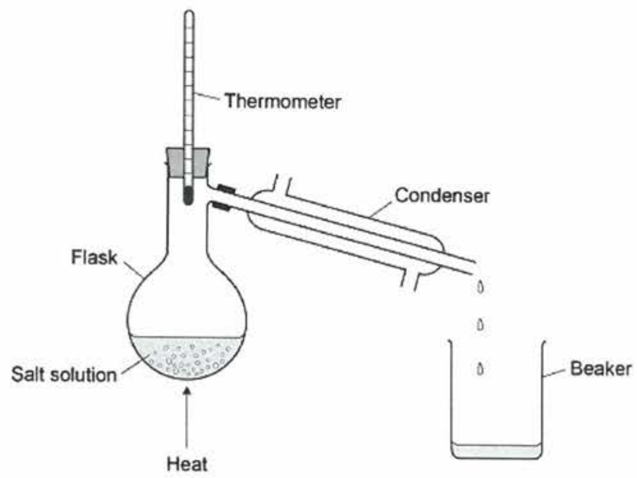
Diagram

(3)

(f) A student distils a sample of salt solution to produce pure water.

Figure 2 shows the apparatus.

Figure 2



What temperature would you expect the thermometer to show?

Tick (✓) **one** box.

0 °C ☐

10 °C ☐

50 °C ☐

100 °C ☐

(1)

(g) Describe how the process of distillation shown in **Figure 2** produces pure water from salt solution.

___

___

___

___

(4)
(Total 13 marks)

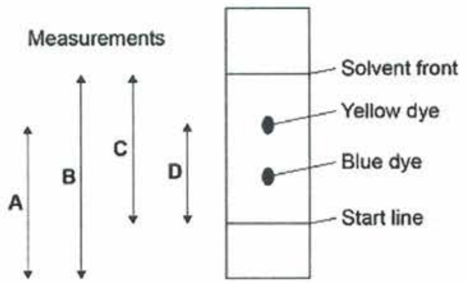
Q19.

This question is about ink.

A student investigated green ink using paper chromatography in a beaker.

The diagram below shows:

- the results the student obtained
- measurements **A**, **B**, **C** and **D** the student could make.



(a) The student calculated the R_f value of the blue dye.

The student measured:

- the distance moved by the blue dye = 2.7 cm
- the distance moved by the solvent = 9.0 cm

Calculate the R_f value of the blue dye.

Use the equation:

$$R_f = \frac{\text{distance moved by dye}}{\text{distance moved by solvent}}$$

R_f = ____________

(2)

(b) Which measurements on the diagram above are needed to calculate the R_f value of

the yellow dye?

Tick (✓) **one** box.

A and **B** ☐

A and **C** ☐

B and **D** ☐

C and **D** ☐

(1)

(c) Paper chromatography has a stationary phase and a mobile phase.

Draw **one** line from each phase to the identity of that phase in the student's investigation.

Phase	Identity
	Beaker
Mobile phase	Ink
	Paper
Stationary phase	Solvent
	Start line

(2)

The green ink contains 85% yellow dye and 15% blue dye.

(d) Determine the simplest whole number ratio of yellow dye : blue dye in the green ink.

Yellow dye : Blue dye = ________ : ________

(1)

(e) Which word correctly describes the green ink?

Tick (✓) **one** box.

Compound ☐

Element ☐

Formulation ☐

Solvent ☐

(1)

(f) The student repeated the investigation using green ink containing 75% yellow dye and 25% blue dye.

What would happen to the R_f value of the yellow dye?

Tick (✓) **one** box.

The R_f value would decrease. ☐

The R_f value would increase. ☐

The R_f value would stay the same. ☐

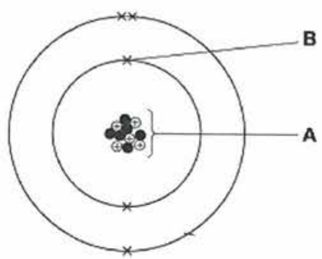
(1)
(Total 8 marks)

Q20.

This question is about atomic structure.

Figure 1 represents an atom of element **Z**.

Figure 1



(a) Name the parts of the atom labelled **A** and **B**.

Choose answers from the box.

electron	**neutron**	**nucleus**	**proton**

A ____________________

B ____________________

(2)

(b) Which particle has the lowest mass?

Choose the answer from the box.

electron	**neutron**	**nucleus**	**proton**

____

(1)

(c) Which group of the periodic table contains element **Z**?

Use **Figure 1**.

Group ____________________

(1)

(d) Give the atomic number and the mass number of element **Z**.

Use **Figure 1**.

Choose answers from the box.

1	**5**	**6**	**11**	**16**

Atomic number ____________________

Mass number ____________________

(2)

Bromine has two different types of atom.

The atoms have a different number of neutrons but the same number of protons.

(e) What is the name for this type of atom?

Tick (✓) **one** box.

Compound ☐

Ion ☐

Isotope ☐

Molecule ☐

(1)

(f) The different types of bromine atom can be represented as $^{79}_{35}Br$ and $^{81}_{35}Br$

The relative atomic mass (A_r) of bromine is 80

Which statement is true about the number of each type of atom in bromine?

Tick (✓) **one** box.

There are fewer $^{79}_{35}Br$ atoms than $^{81}_{35}Br$ atoms. ☐

There are more $^{79}_{35}Br$ atoms than $^{81}_{35}Br$ atoms. ☐

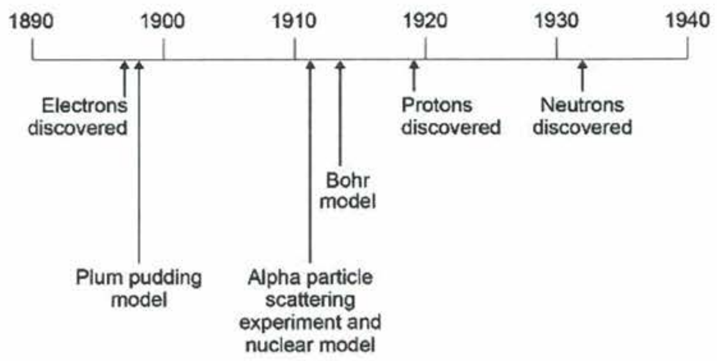
There are the same number of $^{79}_{35}Br$ atoms and $^{81}_{35}Br$ atoms. ☐

(1)
(Total 8 marks)

Q21.

This question is about the development of scientific theories.

The diagram below shows a timeline of some important steps in the development of the model of the atom.



(a) The plum pudding model did not have a nucleus.

Describe **three** other differences between the nuclear model of the atom and the plum pudding model.

1 ______________________________

2 ______________________________

3 ______________________________

(3)

(b) Niels Bohr adapted the nuclear model.

Describe the change that Bohr made to the nuclear model.

____

(2)

(c) Mendeleev published his periodic table in 1869.

Mendeleev arranged the elements in order of atomic weight.

Mendeleev then reversed the order of some pairs of elements.

A student suggested Mendeleev's reason for reversing the order was to arrange the elements in order of atomic number.

Explain why the student's suggestion **cannot** be correct.

Use the diagram above.

____

(2)

(d) Give the correct reason why Mendeleev reversed the order of some pairs of elements.

____

____

(1)
(Total 8 marks)

Q22.

This question is about atoms.

Atoms contain three types of particle:

- electrons
- neutrons
- protons.

(a) Which particle has no electrical charge?

Tick (✓) **one** box.

Electron ☐

Neutron ☐

Proton ☐

(1)

(b) Which particles have the same relative mass?

Tick (✓) **one** box.

An electron and a neutron ☐

An electron and a proton ☐

A neutron and a proton ☐

(1)

(c) The formula of a compound is N_2O

How many of each type of atom are in one molecule of N_2O?

Nitrogen __________

Oxygen __________

(2)

An atom of element **Z** contains:

- 3 electrons
- 4 neutrons
- 3 protons.

(d) Give the name of element **Z**.

Use the periodic table.

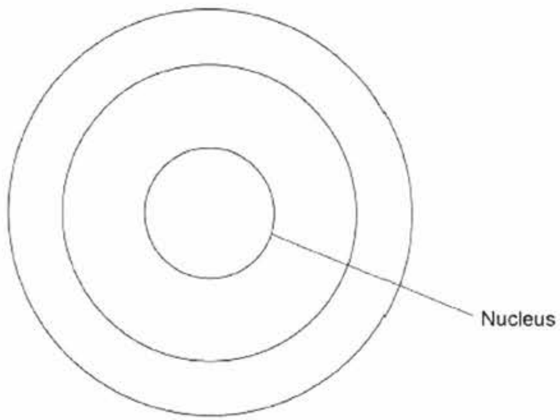
____

(1)

(e) Complete the figure below to show the position of the particles in an atom of element **Z**.

Use the symbols:

× = electron
● = neutron
O = proton



(4)
(Total 9 marks)

Q23.

This question is about carbon.

(a) Which type of substance is carbon?

Tick (✓) **one** box.

Compound ☐

Element ☐

Mixture ☐

(1)

(b) Carbon has isotopes with mass numbers 12, 13 and 14.

Complete the sentences.

Choose answers from the box.

electrons	ions	molecules	neutrons	protons

The isotopes of carbon have the same number of ____________.

The isotopes of carbon have a different number of ____________.

(2)

(c) 12 g of carbon contains 6.02×10^{23} atoms.

Which expression is used to calculate the mass of one atom of carbon?

Tick (✓) **one** box.

$\frac{12}{6.02 \times 10^{23}}$ ☐

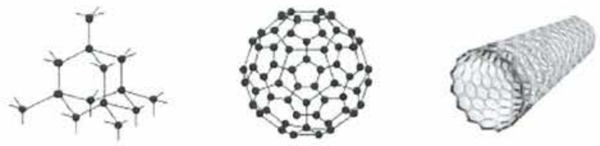
$\frac{6.02 \times 10^{23}}{12}$ ☐

$12 \times 6.02 \times 10^{23}$ ☐

(1)

(d) **Figure 1** shows diagrams that represent different forms of carbon.

Figure 1



Which diagram in **Figure 1** represents Buckminsterfullerene?

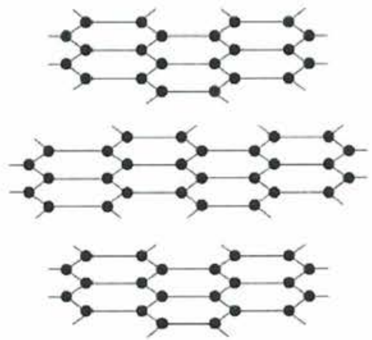
Tick (✓) **one** box.

A ☐ B ☐ C ☐

(1)

(e) **Figure 2** represents part of the structure of graphite.

Figure 2



Draw **one** line from each property of graphite to the structural feature that is the reason for that property.

Property

Graphite conducts electricity.

Graphite is soft.

Structural feature

Graphite has hexagonal rings of carbon atoms.

The bonds between carbon atoms in the layers are strong.

There are no covalent bonds between layers of atoms.

There are delocalised electrons in graphite.

(2)
(Total 7 marks)

Q24.

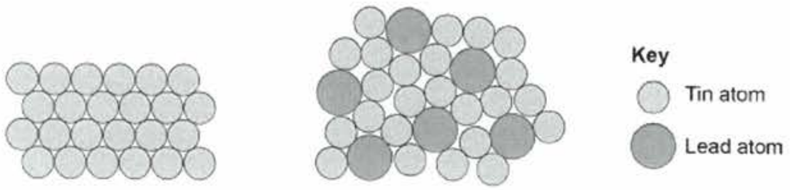
This question is about alloys.

Solders are alloys of tin and lead.

Different solders have different percentages of tin and lead.

Figure 1 shows the arrangement of atoms in pure tin and in a solder.

Figure 1



Pure tin **Solder**

(a) The solder in **Figure 1** has 6 lead atoms for every 24 tin atoms.

Determine the percentage of atoms that are lead atoms in the solder in **Figure 1**.

Percentage of lead atoms = ________ %

(3)

(b) Explain why solder is harder than pure tin.

Complete the sentences.

Use **Figure 1**.

In solder the layers are distorted.

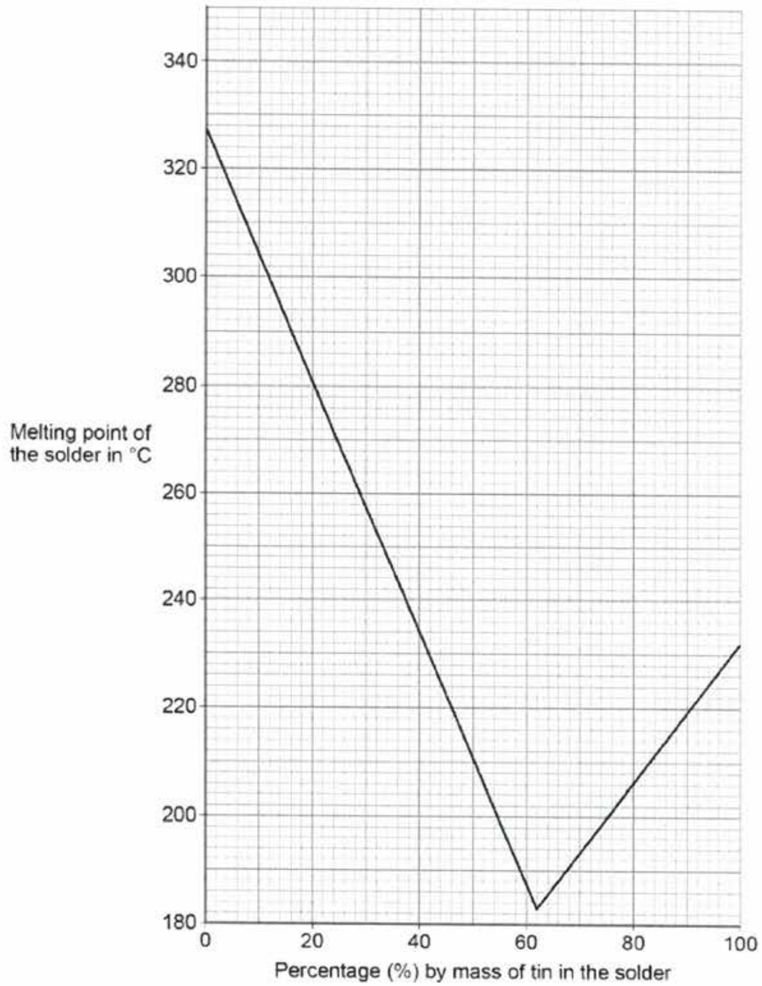
This is because the atoms of tin and lead have different ________.

Therefore the layers cannot easily ________.

(2)

Figure 2 shows how the melting point of the solder changes with the percentage by mass of tin in the solder.

Figure 2



(c) Describe what happens to the melting point of the solder as the percentage by mass of tin increases.

Use data from **Figure 2**.

(3)

(d) What is the melting point of pure tin?

Use **Figure 2**.

Melting point of pure tin = ___________ °C

(1)

(e) What happens to the atoms in pure tin as the tin melts?

Tick (✓) **one** box.

The atoms gain energy and their arrangement becomes less ordered.	☐
The atoms gain energy and their arrangement becomes more ordered.	☐
The atoms lose energy and their arrangement becomes less ordered.	☐
The atoms lose energy and their arrangement becomes more ordered.	☐

(1)

(Total 10 marks)

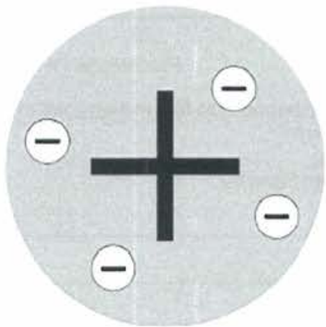
Q25.

Discoveries in chemistry led to a better understanding of atomic structure.

(a) Atoms were originally thought to be tiny spheres that could not be divided.

The plum pudding model of the atom was then developed.

The figure below represents the plum pudding model of the atom.



Describe the plum pudding model of the atom.

____

____

____

____

(2)

(b) Atoms contain electrons, neutrons and protons.

Write these three particles in order of their discovery.

Earliest ___________________

____

Latest ___________________

(1)

Very few atoms of the element tennessine (Ts) have ever been identified.

The atomic number of tennessine is 117

(c) Predict the number of outer shell electrons in an atom of tennessine.

Give **one** reason for your answer.

Use the periodic table.

Number of outer shell electrons _______

Reason ____

–

____

(2)

(d) Tennessine was first identified by a small group of scientists in 2010.

Suggest **one** reason why tennessine was **not** accepted as a new element by other scientists until 2015.

____

____

(1)

(e) The discovery of isotopes explained why some relative atomic masses are not whole numbers.

Element **R** has two isotopes.

The table below shows the mass numbers and percentage abundances of the isotopes of element **R**.

Mass number	Percentage abundance (%)
6	7.6

7	92.4

Calculate the relative atomic mass (A_r) of element **R**.

Give your answer to 1 decimal place.

Relative atomic mass (1 decimal place) = ________________

(3)

(Total 9 marks)

Mark schemes

Q1.

(a) D 1

(b) C 1

(c) sections **A**, **B** and **C** 1

(d) can be bent and shaped 1

good conductor of electricity 1

(e) evidence of the outer electron on the potassium atom moving to leave a potassium ion with no outer electrons

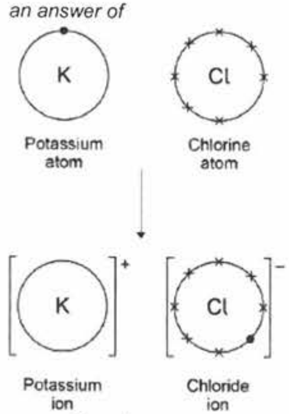
allow any combination of ×, •, ○, e(-) for electrons

ignore any inner shells

allow potassium ion with eight outer electrons 1

chloride ion with eight outer electrons

an answer of



*scores **2** marks* 1

(f) B 1

(g) A 1

[9]

Q2.

(a) 6 1

(b) 7 1

(c) 6 1

(d) C_2F_6 1

(e) only intermolecular forces are weak 1

(f) spherical 1

(g) 3 1

(h) giant structure

allow lattice 1

(of atoms joined by) covalent bonds 1

each carbon / atom forms four bonds 1

[10]

Q3.

(a) (model **A**) plum pudding

allow Thomson (model) 1

(model **B**) Bohr

allow nuclear (model)

allow planetary (model)

allow Rutherford-Bohr (model) 1

(b) **Level 2:** Scientifically relevant features are identified; the way(s) in which they are similar / different is made clear and (where appropriate) the magnitude of the similarity / difference is noted. 3–4

Level 1: Relevant features are identified and differences noted. 1–2

No relevant content 0

Indicative content

Similarities

- both contain electrons

- both are neutral overall

Differences

- model **A** has no nucleus
  or
  the model used today has a nucleus
- model **A** has no protons
  or
  the model used today has protons
- model **A** has no neutrons
  or
  the model used today has neutrons
- model **A** has positive charge spread throughout the atom
  or
  model **A** is a ball of positive charge
- the model used today has the positive charge in the centre
- model **A** the electrons are distributed randomly
- the model used today has electrons in shells / energy levels
- the mass was spread throughout model **A**
- the mass is concentrated at the centre of the model used today
- model **A** does not have empty space
- model used today is mostly empty space

(c) atoms with the same number of protons

allow atoms of the same element

allow atoms with the same atomic number 1

with different numbers of neutrons

ignore references to electrons 1

[8]

Q4.

(a) each calcium atom loses two electrons 1

(and) each chlorine atom gains one electron

*allow **1** mark for calcium atoms lose electrons **and** chlorine atoms gain electrons* 1

(so) one calcium atom reacts with two chlorine atoms 1

(to form) Ca^{2+} ions **and** Cl^- ions
or
(to form) calcium ion(s) **and** chloride ion(s)

allow (to form) ions with full outer shells *allow energy level for shell* 1

(b) the ions cannot move
allow the ions are in fixed positions 1

(c) hydrogen
allow H_2 1

(d) $2\ Cl^- \rightarrow Cl_2 + 2\ e^-$ 1

(e) Cu^{2+} / copper ions are blue
and
CrO_4^{2-} / chromate ions are yellow
allow cathode for negative electrode
allow anode for positive electrode
allow attraction for movement 1

(because) Cu^{2+} / copper ions move to the negative electrode 1

(and also) CrO_4^{2-} / chromate ions move to the positive electrode 1

[10]

Q5.

(a) (thermal) energy is transferred
allow heat is transferred 1

by delocalised electrons 1

(b) (the alloy / mixture has) different sized atoms 1

(so the) layers are distorted 1

(so the) layers cannot easily slide
allow (positive / metal) ions for atoms throughout
allow (so the) atoms cannot slide over each other 1

(c) $2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$ 1

(d) $1\ Fe^{2+} : 2\ Fe^{3+} : 4\ O^{2-}$ 1

(e) (M_r Fe_3O_4 =) 232 1

(% Fe =) $\frac{3 \times 56}{232} \times 100$
allow $\frac{168}{232} \times 100$
allow correct use of an incorrectly determined M_r using the values of A_r given in the question 1

= 72.4 (%)
allow 72.41379 correctly rounded to at least 2 significant figures 1

(f) (40.0 kg =) 40 000 (g)
*a maximum of **4** marks can be awarded for a method which determines and uses the volume of iron oxide as a gas* 1

(moles $Fe_2O_3 = \frac{40\ 000}{160}$ =) 250
allow correct use of an incorrectly converted or unconverted mass 1

(moles $CO_2 = 250 \times \frac{3}{2}$ =) 375
allow correct use of an incorrectly determined number of moles of Fe_2O_3 1

(volume of CO_2 =) 375 × 24
allow correct use of an incorrectly determined number of moles of CO_2 1

= 9000 (dm^3) 1

[15]

Q6.

(a) alloy 1

reinforcement 1

(b) burning (of methane) releases carbon dioxide
allow burning methane
ignore methane is a greenhouse gas 1

decomposition (of limestone) releases carbon dioxide
allow decomposition of limestone 1

(c) hydrochloric acid

limewater 1

(d) (pre-stressed concrete) can bear the weight of (heavy) traffic 1

allow converse for plain concrete

allow (pre-stressed concrete) bridge is less likely to collapse 1

(because pre-stressed concrete is) stronger

*do **not** accept (because prestressed concrete is) more dense* 1

(e) any **two** from:

(plain concrete slabs)

- are cheaper
- will be lighter (to transport / lay)
- do not need to carry vehicles

allow converse for pre-stressed concrete 2

[10]

Q7.

(a) proton 1

(b) electron 1

(c) 7 1

4 1

in this order only

(d) isotopes 1

(e) neutron 1

(f) $\frac{(10 \times 20) + (11 \times 80)}{100}$ 1

= 10.8 1

*an answer of 10.8 scores **2** marks*

(g) $\frac{0.2}{10000}$ 1

= 2×10^{-5} (nm)

allow 0.00002 (nm) 1

an answer of 2×10^{-5} (nm) scores 2 marks

[10]

Q8.

(a) **A** 1

(b) **D** 1

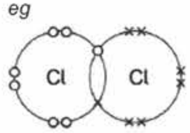
(c) **C** 1

(d) **E** 1

(e) bonding pair of electrons drawn

electrons can be dots, crosses or $e^{(-)}$ in any combination

eg



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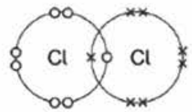

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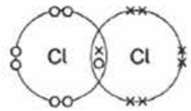


*do **not** accept if electrons added to outer shells outside overlap* 1

(f) weak forces between molecules 1

(g) MnO 1

(h) ions move around in the liquid 1

[8]

Q9.

(a) 13 (protons)

The answers must be in the correct order.

if no other marks awarded, award ***1*** *mark if number of protons and electrons are equal*

1

14 (neutrons)

1

13 (electrons)

1

(b) has three electrons in outer energy level / shell

allow electronic structure is 2.8.3

1

(c) **Level 3 (5–6 marks):**
A detailed and coherent comparison is given, which demonstrates a broad knowledge and understanding of the key scientific ideas. The response makes logical links between the points raised and uses sufficient examples to support these links.

Level 2 (3–4 marks):
A description is given which demonstrates a reasonable knowledge and understanding of the key scientific ideas. Comparisons are made but may not be fully articulated and / or precise.

Level 1 (1–2 marks):
Simple statements are made which demonstrate a basic knowledge of some of the relevant ideas. The response may fail to make comparisons between the points raised.

0 marks:
No relevant content.

Indicative content

Physical
Transition elements

- high melting points
- high densities
- strong
- hard

Group 1

- low melting points
- low densities
- soft

Chemical
Transition elements

- low reactivity / react slowly (with water or oxygen)
- used as catalysts
- ions with different charges
- coloured compounds

Group 1

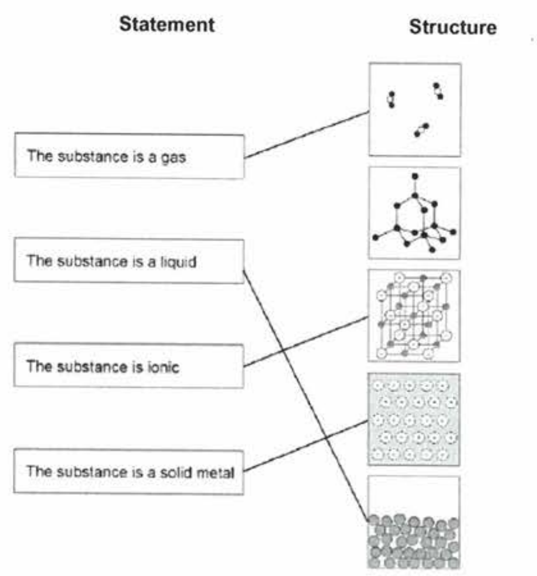
- very reactive / react (quickly) with water / non-metals
- not used as catalysts
- white / colourless compounds
- only forms a +1 ion

6

[10]

Q10.

(a)



more than one line drawn from a variable negates the mark

4

(b) Carbon

1

(c) It has delocalised electrons

1

(d) the atoms / particles / ions are different sizes

do ***not*** *accept molecules*

1

so there are no rows / layers to slide

accept the layers are disrupted

1

(e) $\frac{2}{27} \times 100$

1

7.4%

1

allow 7.4% with no working shown for ***2*** *marks*

(f) Mixture

1

[11]

Q11.

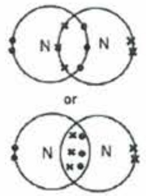
(a) six electrons in the overlap

allow dots, crosses or $e^{(-)}$ for electrons

1

2 non-bonding electrons on each nitrogen atom

***2** marks for an answer of:*



1

(b) weak forces

1

between molecules
or
intermolecular

do not allow references to covalent bonding between molecules

1

(which) need little energy to overcome

1

(c) each (carbon) atom forms three covalent bonds

1

forming layers (of hexagonal rings)

1

(soft)
(because) layers can slide over each other

1

(conducts electricity)
(because of) delocalised electrons

1

(d) molecules are spherical

1

(so molecules) will roll

1

(e) surface area (= 20 × 20 × 6) = 2400 (nm^2)

1

volume (= 20^3) = 8000 (nm^3)

1

ratio = 0.3 (nm^3): 1 (nm^3)
ratio = 0.3 (nm^3): 1 (nm^3)
or
1 (nm^3): 3.33 (nm^3)

1

(f) (nanoparticles) have a larger surface area to volume ratio

1

so less can be used for the same effect

1

[16]

Q12.

(a) **J**

1

(b) **M** and **Q**

either order

1

(c) **Q**

1

(d) **M**

1

(e) **L**

1

(f) **Level 3 (5-6 marks):**
A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given.

Level 2 (3-4 marks):
Some logically linked reasons are given. There may also be a simple judgement.

Level 1 (1-2 marks):
Relevant points are made. They are not logically linked.

Level 0
No relevant content

Indicative content

comparative points
- both tables have more than one element in a box
- both have similar elements in the same column
- both are missing the noble gases
- both arranged elements in order of atomic weight

advantages of Mendeleev / disadvantages of Newlands
- Newlands did not leave gaps for undiscovered elements
- Newlands had many more dissimilar elements in a column
- Mendeleev left gaps for undiscovered elements
- Mendeleev changed the order of some elements (e.g. Te and I)

points which led to the acceptance of Mendeleev's table

- Mendeleev predicted properties of missing elements
- elements with properties predicted by Mendeleev were discovered
- Mendeleev's predictions turned out to be correct
- elements were discovered which fitted the gaps

6

[11]

Q13.

(a) mass number

allow the number of protons + neutrons

1

(b) 6.02×10^{23}

1

(c) **Level 2 (3-4 marks):**
Scientifically relevant features are identified; the ways in which they are similar / different is made clear.

Level 1 (1-2 marks):
Relevant features are identified and differences noted.

Level 0
No relevant content.

Indicative content

similarities

- both have positive charges
- both have (negative) electrons
- neither has neutrons

differences

plum pudding model	nuclear model
ball of positive charge (spread throughout)	positive charge concentrated at the centre
electrons spread throughout (embedded in the ball of positive charge)	electrons outside the nucleus
no empty space in the atom	most of the atom is empty space
mass spread throughout	mass concentrated at the centre

4

(d) $$\frac{(24 \times 78.6) + (25 \times 0.1) + (26 \times 11.3)}{100}$$

or
$(24 \times 0.786) + (25 \times 0.101) + (26 \times 0.113)$

1

$= 24.3$

1

*an answer of 24.3 scores **2** marks*

[8]

Q14.

(a) B

1

(b) C

1

(c) A

1

(d) sum of protons and neutrons

allow number of protons and neutrons

1

(e) between 69.5 and 70.0

1

(f) Chadwick provided the evidence to show the existence of neutrons

allow Chadwick discovered neutrons

1

(this was necessary because) isotopes have the same number of protons

allow (this was necessary because) isotopes have the same atomic number

or
(this was necessary because) isotopes are atoms of the same element

ignore isotopes have the same number of electrons

1

but with different numbers of neutrons

allow but with different mass (numbers)

1

[8]

Q15.

(a) nucleus

1

neutron

1

neutron

1

electron

1

proton

1

must be in this order

(b) $(A_r)\ \frac{(63 \times 70) + (65 \times 30)}{100}$ 1

= 63.6 1

*an answer of 63.6 scores **2** marks*

(c) copper / Cu

*allow ecf from answer to question **(b)*** 1

(d) $\frac{1.2 \times 10^{-10}}{10\,000}$

or

$1.2 \times 10^{-10} \times 1 \times 10^{-4}$ 1

$= 1.2 \times 10^{-14}$ (m) 1

*an answer of 1.2×10^{-14} (m) scores **2** marks*
*a correct answer not in standard form scores **1** mark*

[10]

Q16.

(a) (neutron) 1 0

both needed
allow (neutron) 1 neutral 1

proton 1 (+1)

both needed 1

(b) number of protons plus neutrons

allow number of protons and neutrons
ignore protons and neutrons unqualified
*do **not** accept references to mass or relative mass of protons and / or neutrons* 1

(c) (the isotopes contain) different numbers of neutrons 1

(d) most (alpha) particles passed (straight) through (the gold foil) 1

(so) the mass of the atom is concentrated in the nucleus / centre
or
(so) most of the atom is empty space 1

some (alpha) particles were deflected / reflected 1

(so) the atom has a (positively) charged nucleus / centre

if not awarded for MP2 allow (so) the mass of the atom is concentrated in the nucleus / centre. 1

[8]

Q17.

(a)

ignore reference to atomic structure
ignore references to Cr, Mn and Mo

any **one** from:

- so elements / iodine / tellurium were in groups with similar properties
- iodine has similar properties to Br / Cl / F / Group 7
  allow corresponding argument in terms of tellurium
- iodine has different properties to Se / S / O / Group 6
  allow corresponding argument in terms of tellurium

1

(b)

ignore reference to atomic structure

Mendeleev had predicted properties of missing elements 1

elements were discovered (that filled the spaces / gaps) 1

properties (of these elements) matched Mendeleev's predictions

allow atomic weights (of these elements) fitted in the spaces / gaps 1

*if no other mark awarded, allow **1** mark for in previous versions of the periodic table the pattern of similar properties broke down* 1

(c) relative atomic mass 1

(d) (increasing) atomic / proton number

ignore (increasing) electron number
*do **not** accept relative atomic / proton number* 1

(e) (formula) At_2

ignore incorrect state symbol 1

(state) solid

allow (s)
ignore s 1

(f) any **two** from:
- flame
  allow burns
- (white) solid forms
  allow (white) smoke forms
- colour of gas / chlorine disappears / fades

2

[10]

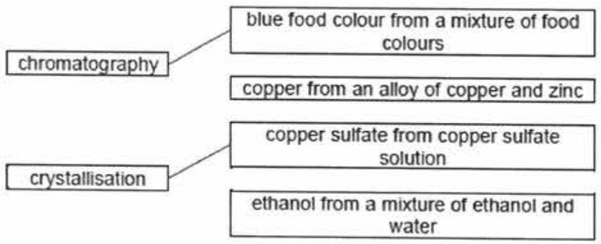
Q18.

(a) B 1

(b) D 1

(c) E 1

(d)



additional line from a box negates the mark for that box

2

(e) (filter) funnel containing filter paper 1

suitable vessel for collecting filtrate 1

sand **and** water labelled in correct place 1

(f) 100 °C 1

(g) any **four** from:

- solution is heated
- water evaporates
  allow water boils / vaporises
- the vapour cools in the condenser
- the vapour condenses
  or
  the vapour turns to a liquid
- (pure) water collects in the beaker

4

[13]

Q19.

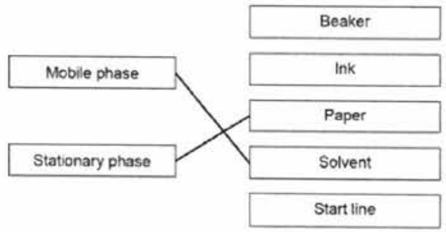
(a) $\frac{2.7}{9.0}$ 1

= 0.3

ignore units 1

(b) **C** and **D** 1

(c)



1

additional line from a box on the left negates the mark for that box 1

(d) 17 : 3 1

(e) formulation 1

(f) the R_f value would stay the same 1

[8]

Q20.

(a) **A** nucleus 1

B electron 1

(b) electron 1

(c) 3 / three 1

(d) (atomic number) 5 1

(mass number) 11 1

(e) isotope 1

(f) there are the same number of $^{79}_{35}Br$ atoms and $^{81}_{35}Br$ atoms 1

[8]

Q21.

(a) any **three** from: (nuclear model)

- mostly empty space
  allow the plum pudding model has no empty space
  allow the plum pudding model is solid
- the positive charge is (all) in the nucleus
  allow in the plum pudding model the atom is a ball of positive charge (with embedded electrons)
  *do **not** accept reference to protons*
- the mass is concentrated in the nucleus
  allow in the plum pudding model the mass is spread out
  *do **not** accept reference to neutrons*
- the electrons and the nucleus are separate
  allow in the plum pudding model the electrons are embedded
  allow in the nuclear model the electrons are in orbits

3

(b) electrons orbit the nucleus
*do **not** accept reference to protons / neutrons*
allow electrons are in energy levels around the nucleus
or
allow electrons are in shells around the nucleus 1

electrons are at specific distances from the nucleus 1

(c) atomic number is the number of protons 1

(and) protons were not discovered until later
ignore electrons / neutrons were not discovered until later 1

(d) so their properties matched the rest of the group

allow converse 1

[8]

Q22.

(a) neutron 1

(b) a neutron and a proton 1

(c) (nitrogen) 2 / two 1

(oxygen) 1 / one 1

(d) lithium
allow Li 1

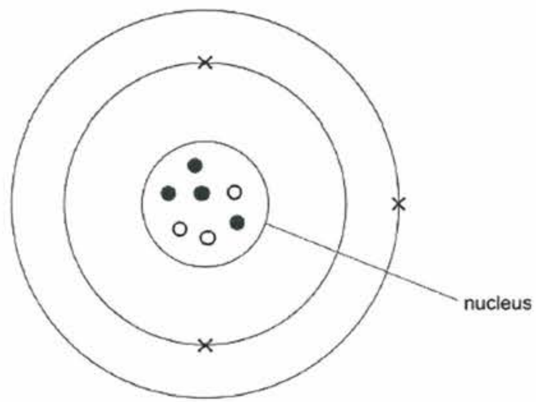
(e) 3 x protons (**O**) in the nucleus 1

4 x neutrons (●) in the nucleus 1

3 x electrons (**X**) in the shells 1

electrons (**X**) arranged 2, 1 1

an answer of



scores **4** marks

[9]

Q23.

(a) element 1

(b) protons

allow electrons 1

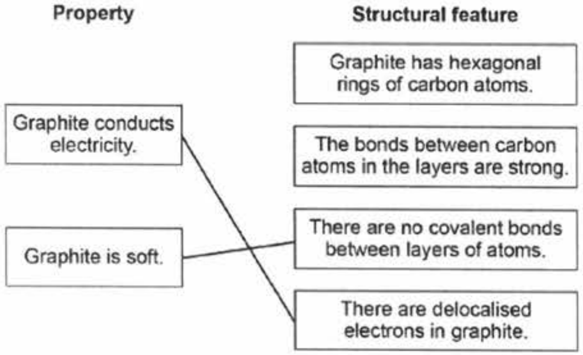
neutrons 1

must be in this order

(c) $\frac{12}{6.02 \times 10^{23}}$ 1

(d) B 1

(e)



*do **not** accept more than **one** line from a box on the left* 2

[7]

Q24.

(a) (total atoms =) 30 1

(percentage =)

$\frac{6}{30} \times 100$

allow correct use of an incorrectly determined total number of atoms 1

= 20 (%) 1

(b) sizes

allow diameters

*do **not** accept shapes* 1

slide (over each other)

allow move over each other 1

(c) (as the percentage by mass of tin increases the) melting point (of solder) decreases 1

to 183 °C

allow a value in the range 182-184 °C

allow to 62% (tin) 1

then increases 1

(d) 232 °C 1

(e) the atoms gain energy and their arrangement becomes less ordered 1

[10]

Q25.

(a) a ball of positive charge

*do **not** accept references to protons, nuclei, neutrons* 1

with (negative) electrons embedded 1

(b) (earliest) electrons
protons
(latest) neutrons 1

(c) (number of outer shell electrons) 7 1

(reason) (tennessine is in) Group 7

allow the number of outer electrons is the same as the group number

allow tennessine is a halogen 1

MP2 is dependent on MP1 being awarded

(d) (time needed for) peer review

allow the idea that other scientists had to check the results 1

(e) (A_r =)

$$\frac{(6 \times 7.6) + (7 \times 92.4)}{100}$$

allow $\frac{45.6 + 646.8}{100}$

allow (6 × 0.076) + (7 × 0.924)

allow 0.456 + 6.468

1

= 6.924

1

= 6.9

allow an answer correctly rounded to 1 decimal place from an incorrect calculation which uses all the data in the table

1

[9]

C5: Chemical Changes - Paper

Lesson	Aiming for 4		Aiming for 6		Aiming for 8	
C5.1 The reactivity series	I can list the order of common metals in the reactivity series.	☐	I can describe oxidation and reduction in terms of gain or loss of oxygen.	☐	I can justify uses of metals in the reactivity series based on their chemical reactivity.	☐
	I can use general equations to write specific word equations for metals listed in the reactivity series reacting with oxygen, water, and acid.	☐	I can write word equations for the metals listed in the reactivity series reacting with oxygen, water, and acid and balance given symbol equations.	☐	I can write balanced symbol equations, with state symbols, for the metals listed in the reactivity series reacting with oxygen, water, and acid.	☐
	I can safely make and record observations.	☐	I can predict observations for the metals listed in the reactivity series reacting with oxygen, water, and acid.	☐	I can evaluate in detail the investigation of metals plus acid, assessing the control of variables and the validity of conclusions drawn from the data collected.	☐
C5.2 Displacement reactions	I can recall a definition of a displacement reaction.	☐	I can explain why a displacement reaction occurs.	☐	I can describe displacement reactions using an ionic equation. (H)	☐
	I can use the reactivity series to determine whether a reaction between a metal and a different metal salt would happen or not.	☐	I can write word equations and straightforward balanced symbol equations for displacement reactions.	☐	I can write balanced symbol equations, with state symbols, for displacement reactions.	☐
	I can safely make and record observations.	☐	I can predict observations for the metals listed in the reactivity series reacting with a different metal salt.	☐	I can determine and explain which species is oxidised and which species (metal atom or ion) is reduced in a displacement reaction in terms of electron transfer. (H)	☐
C5.3 Extracting metals	I can define oxidation and reduction in terms of oxygen.	☐	I can identify species that are being oxidised and reduced in a chemical reaction.	☐	I can explain how carbon or hydrogen can be used to reduce an ore.	☐
	I can describe how metals can be extracted.	☐	I can explain why some metals are found uncombined in the Earth's crust.	☐	I can evaluate the extraction process to obtain a metal from its ore.	☐
C5.4 Salts from metals	I can recall a definition of a salt.	■	I can describe how to make a salt by reacting a metal with an acid.	■	I can explain the reaction between a metal and an acid. (H)	■
	I can name a salt formed between a metal and sulfuric acid or hydrochloric acid.	■	I can write a balanced symbol equation to describe a reaction between a metal and sulfuric acid or hydrochloric acid.	■	I can write ionic and half equations, including state symbols, to describe a reaction between a metal and sulfuric acid or hydrochloric acid. (H)	■
	I can recall a general equation for a metal reacting with an acid and use it to write specific word equations.	☐	I can identify the formula of the salt produced from the reaction between an acid and a metal.	☐	I can identify and explain in detail which species is oxidised and which is reduced (H) reaction.	☐
C5.5 Salts from insoluble bases	I can safely prepare a pure, dry sample of a soluble salt from an insoluble base and a dilute acid.	☐	I can describe a method to prepare a pure, dry sample of a soluble salt from an insoluble substance and a dilute acid.	☐	I can explain the reaction between a metal oxide or metal hydroxide and an acid, including an ionic equation. (H)	☐
	I can name a salt formed between a metal hydroxide or metal oxide and sulfuric acid or hydrochloric acid.	☐	I can write a balanced symbol equation to describe a reaction between a metal hydroxide or oxide and sulfuric acid or hydrochloric acid.	☐	I can generate the formulae of salts given the names of the metal or base and the acid.	☐
	I can recall a general equation for a base reacting with an acid and use it to write specific word equations.	☐	I can explain why the reaction between a base and a dilute acid is a neutralisation reaction.	☐	I can explain how alkalis are a subgroup of bases.	☐
C5.6 Making more salts	I can safely make a salt by reacting a metal carbonate with a dilute acid.	☐	I can describe how to make a dry sample of a salt from reacting a metal carbonate or an alkali with a dilute acid.	☐	I can explain the reaction between ammonia and dilute acids to produce salts and the agricultural importance of the salts.	☐
	I can write a general word equation for metal carbonates and alkalis reacting with dilute acids and use this to make specific word equations.	☐	I can write balanced symbol equations for neutralisation reactions.	☐	I can describe neutralisation using ionic equations, including the ionic equation for a carbonate plus an acid.	☐
C5.7 Neutralisation and the pH scale	I can safely use universal indicator to classify as acidic or alkaline.	☐	I can describe how universal indicator can be used to classify a chemical as acidic or alkaline.	☐	I can evaluate how universal indicator or a data logger can be used to determine the approximate pH of a solution.	☐
	I can describe the pH scale.	☐	I can describe how solutions can be acidic or alkali.	☐	I can use ionic equations to explain how solutions can be acidic or alkali.	☐
	I can recall an example of an alkali, neutral, base, and acidic chemical.	☐	I can describe the relationship between alkalis and bases.	☐	I can explain how the pH of a solution changes as acid or alkali is added.	☐

C5.8 (H) Electronic structures		I can recall examples of strong and weak acids.		I can explain the difference between concentration and strong or weak in terms of acids and alkalis.	
		I can describe how an acid or alkali can be concentrated or dilute.		I can use ionic equations to explain how acids can be strong or weak.	
		I can describe how an acid or alkali can be weak or strong.		I can quantatively explain how the concentration of hydrogen ions relates to the pH number.	

C6: Electrolysis - Paper

Lesson	Aiming for 4		Aiming for 6		Aiming for 8	
C6.1 Introduction to electrolysis	I can define electrolysis.	☐	I can describe electrolysis in terms of movement of ions.	☐	I can explain why electrolysis can only occur when an ionic compound is molten or in aqueous solution.	☐
	I can write a word equation to describe the electrolysis of a molten ionic compound.	☐	I can write a balanced symbol equation including state symbols for the overall electrolysis of a molten ionic compound.	☐	I can describe electrolysis with half equations at the electrodes.	☐
			I can predict the products at each electrode for the electrolysis of a molten ionic compound.	☐	I can explain the classification of the reactions at each electrode as oxidation or reduction.	☐
C6.2 Changes at the electrodes	I can state that oxygen can be produced at the anode when some solutions are electrolysed.	☐	I can describe electrolysis of solutions in terms of movement of ions.	☐	I can explain how hydrogen ions and hydroxide ions can be present in solutions, including a balanced symbol equation with state symbols, for the reversible reaction in which water ionises.	☐
	I can state that hydrogen can be produced at the cathode when some solutions are electrolysed.	☐	I can write a balanced symbol equation including state symbols for the overall electrolysis of a solution.	☐	I can describe electrolysis with half equations at the electrodes.	☐
	I can write a word equation to describe electrolysis of a solution.	☐	I can predict the products at each electrode for the electrolysis of a molten ionic compound or its solution.	☐	I can explain the classification of reactions at the electrodes as oxidation or reduction.	☐
C6.3 Extraction of aluminium	I can state that aluminium can be extracted from aluminium oxide using electrolysis.	☐	I can describe the electrolysis of aluminium oxide.	☐	I can explain why electrolysis is used to extract aluminium from compounds.	☐
	I can write a word equation to describe the electrolysis of aluminium oxide.	☐	I can explain why electrolysis is an expensive metal extraction method and illustrate this with the extraction of aluminium.	☐	I can describe electrolysis with half equations at the electrodes.	☐
			I can explain why cryolite is added to aluminium oxide in the industrial extraction of aluminium.	☐	I can explain the classification of the reactions at each electrode as oxidation or reduction.	☐
C6.4 Electrolysis of aqueous solutions	I can state the products of the electrolysis of brine and a use for each.	☐	I can describe how to electrolyse brine in terms of ions moving.	☐	I can explain the electrolysis of brine using half equations, classifying reactions at the electrode as oxidation or reduction.	☐
	I can safely electrolyse a solution, with guidance provided.	☐	I can predict the products of electrolysis of a solution.	☐	I can evaluate in detail an investigation we have planned and carried out, commenting on our methodology and quality of the data collected.	☐

C6: Electrolysis - Paper

	[illegible]	[illegible]	I can plan and carry out an electrolysis investigation.	☐	I can explain the classification of the reactions at each electrode as oxidation or reduction.	☐

C7: Energy changes

Lesson	Aiming for 4	Aiming for 6	Aiming for 8
C7.1 Exothermic and endothermic reactions	I can define exothermic and endothermic reactions.	I can describe examples of exothermic and endothermic reactions.	I can explain a chemical reaction in terms of energy transfer.
	I can state that energy is conserved in a chemical reaction.	I can explain, using observations from calorimetry, how to classify a reaction as exothermic or endothermic.	I can plan, carry out, and evaluate the errors in a calorimetry investigation.
	I can safely complete a calorimetry experiment for a reaction that takes place in solution.	I can explain in detail how to carry out a calorimetry experiment.	
C7.2 Using energy transfers from reactions	I can state a use of an exothermic reaction and an endothermic reaction.	I can explain how an energy change from a chemical reaction can be used.	I can suggest a chemical reaction for a specific purpose based on the energy change for the reaction.
	I can write word equations for familiar reactions.	I can write balanced symbol equations for familiar reactions.	I can evaluate in detail the uses of exothermic and endothermic reactions.
C7.3 Reaction profiles	I can define activation energy.	I can label activation energy on a reaction profile diagram.	I can explain why chemical reactions need activation energy to start them.
	I can sketch a generic reaction profile diagram for an exothermic or endothermic reaction.	I can generate a specific reaction profile diagram for a given chemical reaction when its energy change is also supplied.	I can use the particle model to explain how a chemical reaction occurs.
		I can identify bonds broken in reactants and new bonds made in products of a reaction.	I can explain energy change in terms of the balance between bond making and bond breaking.
C7.4 Bond energy calculations		I can explain, using the particle model, how reactants become products in a chemical reaction.	I can calculate the energy needed to break the reactant bonds and the energy released when the product bonds are made.
		I can explain why bond breaking is endothermic and bond making is exothermic.	I can calculate the energy change for a reaction, including the correct unit.
		I can define bond energy and identify all the bonds that break and are made in a chemical reaction.	I can explain in terms of bond energies how a reaction is either exothermic or endothermic.
C7.5 Chemical cells and batteries	I can describe a simple cell.	I can explain how potential difference can be changed in a cell.	I can describe an electrochemical cell with half-equations and ionic equations.
	I can describe a battery.	I can interpret data from an electrochemical cell to determine the reactivity of the metals involved.	I can explain why the reactions in an electrochemical cell are redox reactions and determine which species is oxidised or reduced in an electrochemical cell.
	I can give an example of a non-rechargeable battery.	I can explain why non-rechargeable batteries stop working.	I can evaluate the use of non-rechargeable batteries.
C7.6 Fuels cells	I can describe a hydrogen fuel cell.	I can explain how a hydrogen fuel cell produces electricity.	I can describe the reactions in fuel cells using balanced symbol and half equations.

C7: Energy changes

	I can state some uses for hydrogen fuel cells.	☐	I can list the advantages and disadvantages of hydrogen fuel cells.	☐	I can evaluate the use of hydrogen fuel cells instead of rechargeable cells and batteries.	☐
	I can state that hydrogen fuel cells could be an alternative to rechargeable cells and batteries.	☐	I can explain why hydrogen fuel cells are an alternative to rechargeable cells and batteries.	☐	I can determine and explain which species is oxidised and which is reduced in a hydrogen fuel cell	☐

Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The **reactivity** of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have *high* reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have *low* reactivity.

Reactivity series

The reactivity series places metals in order of their reactivity.

Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are non-metals.

Reaction with water	Reaction with acid	Reactivity series: Metal	Reactivity series: Reactivity	Extraction method
fizzes, gives off hydrogen gas	explodes	**potassium**	**high reactivity**	electrolysis
		sodium	Decreasing reactivity	
		lithium		
	fizzes, gives off hydrogen gas	**calcium**		
reacts very slowly		**magnesium**		
		aluminium *(carbon)*		
		zinc		reduction with carbon
		iron		
no reaction	reacts slowly with warm acid	**tin**		
		lead *(hydrogen)*		
	no reaction	**copper**		
		silver		mined from the Earth's crust
		gold	**low reactivity**	

Metal extraction

Some metals, like gold, are so unreactive that they are found as pure metals in the Earth's crust and can be mined.

Most metals exist as compounds in rock and have to be extracted from the rock. If there is enough metal compound in the rock to be worth extracting it is called an **ore**.

Metals that are less reactive than carbon can be extracted by reduction with carbon. For example:

iron oxide + carbon → iron + carbon dioxide

Metals that are more reactive than carbon can be extracted using a process called **electrolysis**.

Reduction and oxidation

If a substance gains oxygen in a reaction, it has been **oxidised**.

If a substance loses oxygen in a reaction, it has been **reduced**.

For example:

iron + oxygen → iron oxide
iron has been oxidised

iron oxide + carbon → iron + carbon dioxide
iron oxide has been reduced

Salts

When acids react with metals or metal compounds, they form salts.

A salt is a compound where the hydrogen from an acid has been replaced by a metal. For example nitric acid, HNO_3, reacts with sodium to form $NaNO_3$. The H in nitric acid is replaced with Na.

The table shows how to name salts.

Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula	HCl	H_2SO_4	HNO_3
Ions formed in solution	H^+ and Cl^-	$2H^+$ and SO_4^{2-}	H^+ and NO_3^-
Type of salt formed	metal chloride	metal sulfate	metal nitrate
Sodium salt example	sodium chloride, $NaCl$	sodium sulfate, Na_2SO_4	sodium nitrate, $NaNO_3$

Displacement reactions

In a **displacement** reaction a *more* reactive element takes the place of a *less* reactive element in a compound.

For example:

copper sulfate + iron → iron sulfate + copper

$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$

Iron is more reactive than copper, so iron displaces the copper in copper sulfate.

Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $CuSO_4(aq)$ can be written as $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$.

The displacement reaction of copper sulfate and iron can be written as:

$$Fe(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Fe^{2+}(aq) + SO_4^{2-}(aq) + Cu(s)$$

The SO_4^{2-} is unchanged in the reaction – it is a **spectator ion**. Spectator ions are removed from the equation to give an **ionic equation**:

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$

Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$

A copper ion gains two electrons to form a copper atom:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

These two equations are called **half equations** – they each show half of the ionic equation.

Reactivity and ions

A metal's reactivity depends on how readily it forms an **ion** by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with iron ions, not copper ions.

Steps for writing an ionic equation (HT only)

1. check symbol equation is balanced
2. identify all aqueous ionic compounds
3. write those compounds out as ions
4. remove spectator ions.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the loss or gain of electrons.

Oxidation is the *loss* of electrons, and reduction is the *gain* of electrons.

In the example displacement reaction:

- iron atoms have been oxidised
- copper ions have been reduced.

Acids and alkalis

Acids are compounds that, when dissolved in water, release H^+ ions. There are three main acids: sulfuric acid H_2SO_4, nitric acid HNO_3, and hydrochloric acid HCl.

Alkalis are compounds that, when dissolved in water, release OH^- ions.

The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

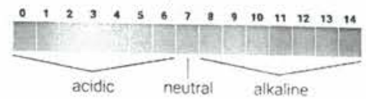
- Aqueous solutions with pH < 7 are acidic.
- Aqueous solutions with pH > 7 are alkaline.
- Aqueous solutions with pH = 7 are neutral.

Indicators

Indicators can show if something is an acid or an alkali.

- **Universal indicator** can also tell us the approximate pH of a solution.
- Electronic pH probes can give us the exact pH of a solution.

The pH scale



Chapter 5: Chemical changes 2

Knowledge organiser

Reactions of acids

Reactions of acids with metals

Acids react with some metals to form salts and hydrogen gas.

magnesium + hydrochloric acid → sodium chloride + hydrogen

Neutralisation reactions

Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form salts and water.

hydrochloric acid + sodium hydroxide → sodium chloride + water

The ionic equation for this reaction is always:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Reactions of acids with metal oxides

Acids react with metal oxides to form salts and water.

hydrochloric acid + sodium oxide → sodium chloride + water

Reactions of acids with metal carbonates

Acids react with metal carbonates to form a salt, water, and carbon dioxide.

hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide

Alkalis and bases

Bases neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form alkaline solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in water. They are **bases**, but are not alkalis.

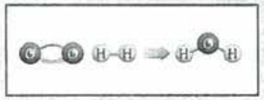
Balancing symbol equations

When writing symbol equations you need to ensure that the number of each atom on each side is equal.

$H_2 + O_2 \rightarrow H_2O$

unbalanced

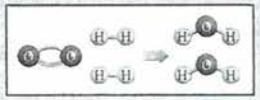
there are 2 hydrogen atoms on each side, but 2 oxygen atoms in the reactants and 1 in the product



$2H_2 + O_2 \rightarrow 2H_2O$

balanced

there are 4 hydrogen atoms on each side, and 2 oxygen atoms on each side



State symbols

A balanced symbol equation should also include state symbols.

State	Symbol
solid	(s)
liquid	(l)
gas	(g)
aqueous or dissolved in water	(aq)

Key terms

Make sure you can write a definition for these key terms.

displacement, electrolysis, extraction, half equation, ion, ionic equation, metal, ore, oxidation, reactivity, reactivity series, redox, reduction, spectator ion, state symbols

Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all **strong acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

- $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
- $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
- $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

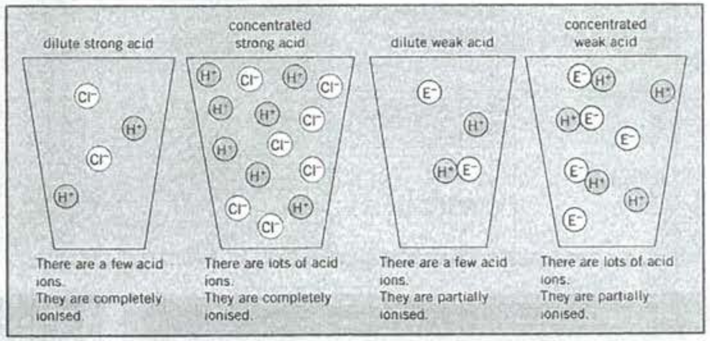
Ethanoic acid, citric acid, and carbonic acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are partially ionised.

For a given concentration, the *stronger* the acid, the *lower* the pH.

Concentrated and dilute acids

Concentration tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a small volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.

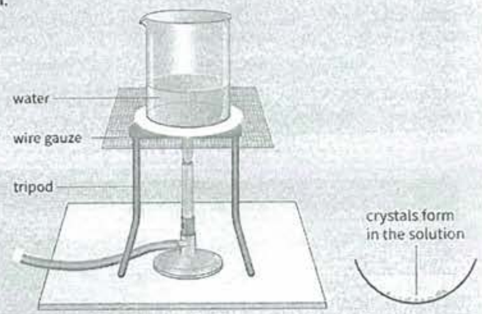


Crystallisation

You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

1. Choose the correct acid and base to produce the salt.
2. Put some of the dilute acid into a flask. Heat gently with a Bunsen burner.
3. Add a small amount of the base and stir.
4. Keep adding the base until no more reacts – the base is now in excess.
5. Filter to remove the unreacted base.
6. Add the remaining solution to an evaporating dish.
7. Use a water bath or electric heater to evaporate the water. The salt crystals will be left behind.



Chapter 5: Chemical changes

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C5 questions	Answers
1	What does reactivity mean?	how vigorously a substance chemically reacts
2	How can metals be ordered by their reactivity?	by comparing their reactions with water, acid, or oxygen
3	What name is given to a list of metals ordered by their reactivity?	reactivity series
4	In terms of electrons, what makes some metals more reactive than others?	they lose their outer shell electron(s) more easily
5	Why are gold and silver found naturally as elements in the Earth's crust?	they are very unreactive
6	What is an ore?	rock containing enough of a metal compound to be economically worth extracting
7	How are metals less reactive than carbon extracted from their ores?	reduction with carbon
8	In terms of oxygen, what is oxidation?	addition of oxygen
9	In terms of oxygen, what is reduction?	removal of oxygen
10	Why can metals like potassium and aluminium not be extracted by reduction with carbon?	they are more reactive than carbon
11	How are metals more reactive than carbon extracted from their ores?	electrolysis
12	What is a displacement reaction?	a more reactive substance takes the place of a less reactive substance in a compound
13	What is an ionic equation?	equation which gives some substances as ions and has spectator ions removed
14	What type of substance is given as ions in an ionic equation?	ionic compounds in solution (or liquid)
15	What is a spectator ion?	ion that is unchanged in a reaction
16	What is a half equation?	equation that shows whether a substance is losing or gaining electrons
17	In terms of electrons, what is oxidation?	loss of electrons
18	In terms of electrons, what is reduction?	gain of electrons
19	In terms of pH, what is an acid?	a solution with a pH of less than 7
20	In terms of pH, what is a neutral solution?	a solution with a pH of 7
21	In terms of H^+ ions, what is an acid?	a substance that releases H^+ ions when dissolved in water
22	How is the amount of H^+ ions in a solution related to its pH?	the more H^+ ions, the lower the pH
23	What are the names and formulae of three main acids?	hydrochloric acid, HCl; sulfuric acid, H_2SO_4; nitric acid, HNO_3
24	How do you measure the pH of a substance?	universal indicator or pH probe
25	What is a strong acid?	an acid where the molecules or ions completely ionise in water
26	What is a weak acid?	an acid where the molecules or ions partially ionise in water
27	What is a salt?	compound formed when a metal ion takes the place of a hydrogen ion in an acid
28	Which type of salts do sulfuric acid, hydrochloric acid, and nitric acid form?	sulfates, chlorides, nitrates
29	What are the products of a reaction between a metal and an acid?	salt + hydrogen
30	What are the products of a reaction between a metal hydroxide and an acid?	salt + water
31	What are the products of a reaction between a metal oxide and an acid?	salt + water
32	What are the products of a reaction between a metal carbonate and an acid?	salt + water + carbon dioxide
33	What is a base?	substance that reacts with acids in neutralisation reactions
34	What is an alkali?	substance that dissolves in water to form a solution above pH 7
35	What is a neutralisation reaction?	a reaction between an acid and a base to produce water
36	What is the ionic equation for a reaction between an acid and an alkali?	$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
37	How can you obtain a solid salt from a solution?	crystallisation
38	When an acid reacts with a metal, which species is oxidised?	the metal
39	When an acid reacts with a metal, which species is reduced?	hydrogen
40	What are the four state symbols and what do they stand for?	(s) solid, (l) liquid, (g) gas, (aq) aqueous or dissolved in water

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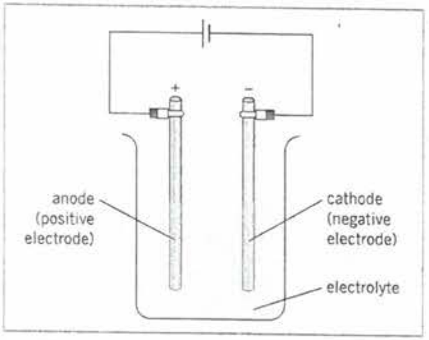
Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric current is passed through an **electrolyte**. An electrolyte is a liquid or solution that contains ions and so can conduct electricity. This causes the ions to move to the **electrodes**, where they form pure elements.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be molten or dissolved, so the ions are free to move.

When an ionic compound is molten:

- The positive metal ions are *attracted* to the **cathode**, where they will *gain* electrons to form the pure metal
- The negative non-metal ions are *attracted* to the **anode**, where they will *lose* electrons and become the pure non-metal.

For example, molten sodium chloride, NaCl, can undergo electrolysis to form sodium at the cathode and chlorine at the anode.

Half equations (HT only)

sodium chloride → sodium + chlorine

$2NaCl(l) \rightarrow 2Na(s) + Cl_2(g)$

- at the cathode:

$2Na^+(l) + 2e^- \rightarrow 2Na(s)$

- at the anode:

$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires less energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo ionisation:

$$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$$

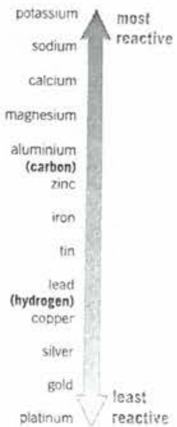
Products at the anode

In In the electrolysis of a solution, if the non-metal contains oxygen then oxygen gas is formed at the anode:

- The $OH^-(aq)$ ions formed from the ionisation of water are attracted to the anode.
- The $OH^-(aq)$ ions lose electrons to the anode and form oxygen gas.
- $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$



Products at the cathode

In the electrolysis of a solution, if the metal is *more* **reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The $H^+(aq)$ ions from the ionisation of water are attracted to the cathode and react with it.
- The $H^+(aq)$ ions gain electrons from the cathode and form hydrogen gas.
- $2H^+(aq) + 2e^- \rightarrow H_2(g)$
- The metal ions remain in solution.

Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

Electrolysis is used if the metal is more reactive than carbon.

Aluminium is extracted from aluminium oxide by electrolysis.

1 The aluminium oxide is mixed with a substance called **cryolite**, which lowers the melting point.
2 The mixture is then heated until it is molten.
3 The resulting molten mixture undergoes electrolysis.

aluminium oxide → aluminium + oxygen

$2Al_2O_3(l) \rightarrow 4Al(l) + 3O_2(g)$

cathode: pure aluminium is formed

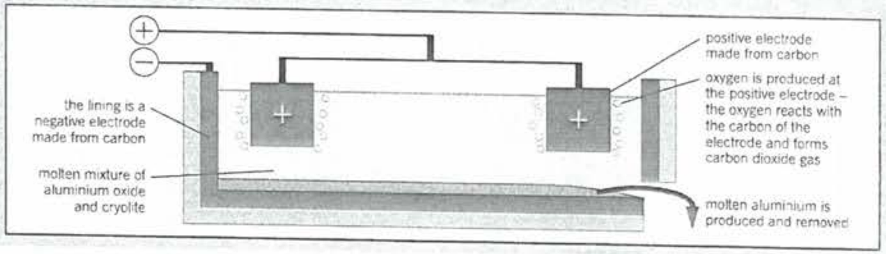
$Al^{3+}(l) + 3e^- \rightarrow Al(l)$

anode: oxygen is formed

$2O^{2-}(l) \rightarrow O_2(g) + 4e^-$

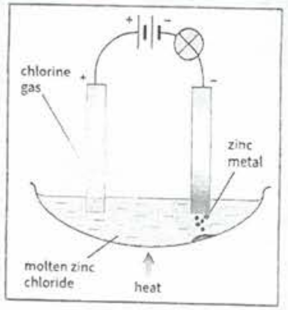
In the electrolysis of aluminium, the anode is made of graphite.

The graphite reacts with the oxygen to form carbon dioxide and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means zinc metal is collected at the cathode and a pale green chlorine gas is collected at the anode. Free ions from the molten zinc chloride are able to move around and carry electric currents, hence why the bulb lights up.



Key terms

Make sure you can write a definition for these key terms.

anode, electrolysis, cathode, electrolyte, cryolite, electrode, reactivity

Chapter 6: Electrolysis

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C6 questions	Answers
1	What is electrolysis?	process of using electricity to extract elements from a compound
2	What is the name of the positive electrode?	anode
3	What is the name of the negative electrode?	cathode
4	What is an electrolyte?	liquid or solution that contains ions and so can conduct electricity
5	Where are metals formed?	cathode
6	Where are non-metals formed?	anode
7	How can ionic substances be electrolysed?	by melting or dissolving them, and then passing a direct current through them
8	Why can solid ionic substances not be electrolysed?	they do not conduct electricity, or the ions cannot move
9	In the electrolysis of solutions, when is the metal *not* produced at the cathode?	when the metal is more reactive than hydrogen
10	In the electrolysis of a metal halide solution, what is produced at the anode?	halogen
11	In the electrolysis of a metal sulfate solution, what is produced at the anode?	oxygen
12	What is the half equation for the ionisation of water?	$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$
13	What metals are extracted from ionic compounds by using electrolysis?	metals that are more reactive than carbon
14	In the electrolysis of aluminium oxide, why is the aluminium oxide mixed with cryolite?	to lower the melting point
15	In the electrolysis of aluminium oxide, what are the anodes made of?	graphite
16	In the electrolysis of aluminium oxide, why do the anodes need to be replaced?	they react with the oxygen being formed

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Chapter 7: Energy changes

Knowledge organiser

Energy changes

During a chemical reaction, energy transfers occur.

Energy can be transferred:

- to the surroundings – **exothermic**
- from the surroundings – **endothermic**

This energy transfer can cause a temperature change.

Energy is always conserved in chemical reactions.

This means that there is the same amount of energy in the Universe at the start of a chemical reaction as at the end of the chemical reaction.

The surroundings

When chemists say energy is transferred from or to "the *surroundings*" they mean "everything that isn't the reaction".

For example, imagine you have a reaction mixture in a test tube. If you measure the temperature in the test tube using a thermometer, the thermometer is then part of the surroundings.

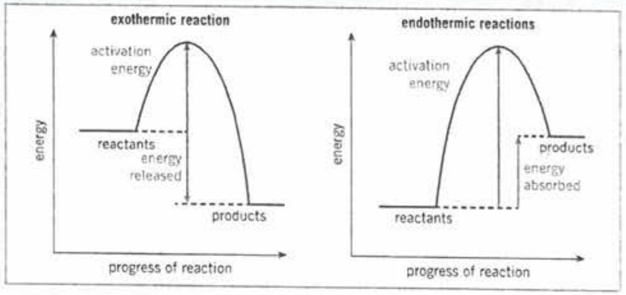
- If the thermometer records an increase in temperature, the reaction in the test tube is exothermic.
- If the thermometer records a decrease in temperature, the reaction in the test tube is endothermic.

Reaction	Energy transfer	Temperature change	Example	Everyday use	Bonds
exothermic	to the surroundings	temperature of the surroundings increases	• **oxidation** • **combustion** • **neutralisation**	• self-heating cans • hand warmers	more energy released when making bonds than required to break bonds
endothermic	from the surroundings	temperature of the surroundings decreases	• **thermal decomposition** • citric acid and sodium hydrogen carbonate	• sports injury packs	less energy released when making bonds than required to break bonds

Reaction profiles

A **reaction profile** shows whether a reaction is exothermic or endothermic.

The **activation energy** is the minimum amount of energy that particles must have to react when they collide.



Bonds (HT only)

Atoms are held together by strong chemical bonds. In a reaction, those bonds are broken and new ones are made between different atoms.

- Breaking a bond requires energy so is endothermic.
- Making a bond releases energy so is exothermic.

Breaking bonds

If a lot of energy is released when making the bonds and only a little energy is required to break them, then overall energy is released and the reaction as a whole is exothermic.

Making bonds

If a little energy is released when making the bonds and a lot is required to break them, then overall energy is taken in and the reaction as a whole is endothermic.

Bond calculations

Different bonds require different amounts of energy to be broken (their **bond energies**). To work out the overall energy change of a reaction, you need to:

1. work out how much energy is required to break all the bonds in the reactants
2. work out how much energy is released when making all the bonds in the products.

overall energy transferred = energy required to break bonds – energy required to make bonds

- A positive number means an endothermic reaction.
- A negative number means an exothermic number.

Chemical cells

In a metal displacement reaction, one metal is oxidised – it loses electrons. These electrons are transferred to another metal, which gains the electrons and so is reduced.

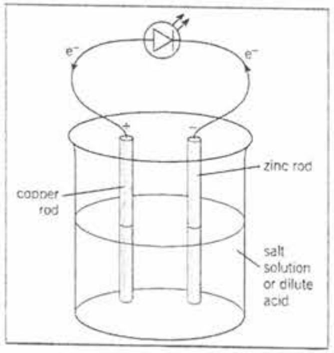
By using a **chemical cell** to conduct this reaction, the electron's movement generates a current.

In the cell shown, the zinc atoms from the electrode lose electrons, turn into ions, and move into the solution.

The electrons travel through the circuit to the copper electrode, causing the LED to light up.

Once at the copper electrode, a metal ion *from the solution* will pick the electrons up and become a metal atom.

The greater the difference in reactivity between the two metals in the cell, the greater the potential difference produced.



Batteries

A **battery** is formed of two or more cells connected in series.

- Some batteries are **rechargeable**. An external electric current is applied, which reverses the reaction.
- Some batteries, like alkaline batteries, are not rechargeable because the reaction is not reversible. Once the reactants are used up, the chemical reaction stops and no more potential differences are released.

Hydrogen fuel cells

Fuel cells use a fuel and oxygen from the air to generate a potential difference.

Hydrogen fuel cells generate electricity from hydrogen and oxygen. The overall reaction is:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

The hydrogen is oxidised to produce water.

There are different types of hydrogen fuel cell. In alkaline fuel cells, the half equations are below:

- $2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$
- $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

Advantages

- the only waste is water
- do not need to be electrically recharged

Disadvantages

- hydrogen is highly flammable and difficult to store
- hydrogen is often produced from non-renewable resources

Key terms

Make sure you can write a definition for these key terms.

activation energy, battery, bond energy, chemical cell, combustion, endothermic, exothermic, fuel cell, neutralisation, oxidation, reaction profile, rechargeable, thermal decomposition

Chapter 7: Energy changes

Retrieval questions

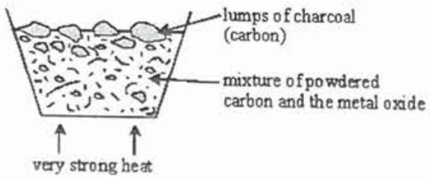
Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	C7 questions	Answers
1	What is an exothermic energy transfer?	transfer to the surroundings
2	What is an endothermic energy transfer?	transfer from the surroundings
3	What is a reaction profile?	diagram showing how the energy changes in a reaction
4	What is the activation energy?	minimum amount of energy required before a collision will result in a reaction
5	What is bond energy?	the energy required to break a bond or the energy released when a bond is formed
6	In terms of bond breaking and making, what is an exothermic reaction?	less energy is required to break the bonds than is released when making the bonds
7	In terms of bond breaking and making, what is an endothermic reaction?	more energy is required to break the bonds than is released when making the bonds
8	How are chemical cells made?	connect two different metals (electrodes) in a solution (electrolyte)
9	What is a battery?	two or more chemical cells connected in series
10	How does the potential difference of a cell depend on the metals that the electrodes are made of?	the bigger the difference in reactivity, the greater the potential difference
11	How can some cells be recharged?	by applying an external current
12	Why can some cells not be recharged?	the reaction cannot be reversed
13	What is a fuel cell?	cell that uses a fuel and oxygen to generate electricity
14	In the hydrogen fuel cell, what is the overall reaction?	$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
15	In the alkaline hydrogen fuel cells, what are the half equations?	$2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$ $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
16	Give an advantage of the hydrogen fuel cell.	only product is water, do not need to be electrically recharged
17	Give a disadvantage of the hydrogen fuel cell.	hydrogen is flammable, difficult to store and is often produced from non-renewable sources

Put paper here

1 A student was trying to extract the metals from lead oxide and aluminium oxide.

She heated each oxide with carbon in a fume cupboard as shown below.



She was able to extract lead from lead oxide but not aluminium from aluminium oxide.

(i) Explain the results of these experiments.

____

____

____

____

____

(ii) Complete this word equation for the reaction between lead oxide and carbon.

lead oxide + carbon → ______________ + ______________

(Total 5 marks)

2 Cassiterite is an ore of the metal tin.

(a) What is an ore?

____

____

(2)

(b) Some metals are obtained by removing oxygen from the metal oxide.

What name do we give to this chemical reaction?

____

(1)

(c) Name **one** metal which must be extracted from its melted ore by electrolysis rather than by using carbon.

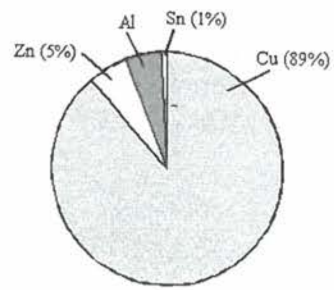
____

(1)

(Total 4 marks)

3 The 50 Eurocent coin is made from an alloy called 'Nordic Gold'.

The pie chart shows the percentage by mass of each metal in 'Nordic Gold'.



(a) (i) Calculate the percentage of aluminium, Al, in the coin.

____

(1)

(ii) The 50 Eurocent coin has a mass of 7 grams.
Calculate the mass of zinc, Zn, in this coin.

____

____

Mass of zinc = ______________ g

(2)

(b) Zinc is extracted by removing oxygen from zinc oxide.

(i) What name is given to a reaction in which oxygen is removed from a substance?

____

(1)

____

____

____

____

(2)

(Total 6 marks)

4 Choose gases from this list to complete the word equations below.

carbon dioxide   hydrogen   nitrogen

oxygen   sulphur dioxide

(a) sodium + water → sodium hydroxide + ____________________ .

(1)

(b) magnesium + ____________________ → magnesium oxide.

(1)

(Total 2 marks)

5 Use the Reactivity Series of Metals on the Data Sheet to help you to answer this question.

The table gives information about the extraction of some metals.

Metal	Date of discovery	Main source	Main extraction method
Gold	Known to ancient civilisations	In the Earth as the metal itself	Physically separating it from the rocks it is mixed with
Zinc	1500	Zinc carbonate	Reduction by carbon
Sodium	1807	Sodium chloride	Electrolysis

(a) Explain why gold is found mainly as the metal itself in the Earth.

____

____

(1)

(b) One of the reactions involved in producing zinc is represented by this equation.

$ZnO + C \rightarrow Zn + CO$

Explain why carbon can be used to extract zinc.

____

____

(1)

(c) Sodium is one of the most abundant metals on Earth.

Explain, as fully as you can, why sodium was not extracted until 1807.

____

____

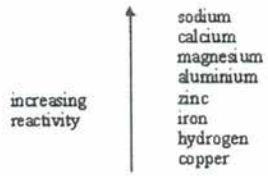
____

____

(2)

(Total 4 marks)

6 Part of a reactivity series is:



(a) Carbon is used in blast furnaces to obtain iron and zinc from their oxides, but electrolysis has to be used to obtain aluminium from its oxide.

Draw an arrow on the reactivity series above to show where carbon fits into the series.

(1)

(b) Predict the method of extraction used to obtain calcium from its ore and explain your answer.

____

____

____

(2)

(c) The formula for zinc oxide is ZnO. Write a balanced equation for the extraction of zinc in the blast furnace.

____

(2)

(Total 5 marks)

7 The table gives information about some metals.

Name of the metal	Cost of one tonne of the metal in December 2003 (£)	Percentage of the metal in the crust of the earth (%)
Aluminium	883	8.2
Platinum	16720000	0.0000001
Iron	216	4.1
Gold	8236800	0.0000001

(a) Use information in the table to suggest why gold and platinum are very expensive metals.

(1)

(b) Aluminium and iron are made by *reduction* of their ores.

(i) Name the element that is removed from the ores when they are *reduced*.

(1)

(ii) Use the reactivity series on the Data Sheet to suggest a metal that would reduce aluminium ore.

(1)

(c) Aluminium is made by the reduction of molten aluminium ore, using a very large amount of electricity.

(i) How is iron ore reduced in a blast furnace to make iron?

(2)

(ii) Suggest why aluminium is more expensive than iron.

(1)
(Total 6 marks)

8 One step in the manufacture of lead is the reduction of lead oxide with carbon. Lead and carbon dioxide are the products of this reaction.

(a) Write a word equation for this reaction.

(1)

(b) What is meant by "reduction"?

(1)
(Total 2 marks)

9 A student investigated the reactivity of three different metals.

This is the method used.

1. Place 1 g of metal powder in a test tube.
2. Add 10 cm^3 of metal sulfate.
3. Wait 1 minute and observe.
4. Repeat using the other metals and metal sulfates.

The student placed a tick in the table below if there was a reaction and a cross if there was no reaction.

	Zinc	**Copper**	**Magnesium**
Copper sulfate	✓	x	✓
Magnesium sulfate	x	x	x
Zinc sulfate	x	x	✓

(a) What is the dependent variable in the investigation?

Tick **one** box.

Time taken ☐

Type of metal ☐

Volume of metal sulfate ☐

Whether there was a reaction or not ☐

(1)

(b) Give **one** observation the student could make that shows there is a reaction between zinc and copper sulfate.

____

____

(1)

(c) The student used measuring instruments to measure some of the variables.

Draw **one** line from each variable to the measuring instrument used to measure the variable.

Variable	**Measuring instrument**
	Balance
	Measuring cylinder
Mass of metal powder	
	Ruler
	Burette
Volume of metal sulfate	
	Theromometer
	Test tube

(2)

(d) Use the results shown in table above to place zinc, copper and magnesium in order of reactivity.

Most reactive ________________

↕ ________________

Least reactive ________________

(1)

(e) Suggest **one** reason why the student should **not** use sodium in this investigation.

____

____

(1)

(f) Which metal is found in the Earth as the metal itself?

Tick **one** box.

Calcium ☐

Gold ☐

Lithium ☐

Potassium ☐

(1)

(g) Iron is found in the Earth as iron oxide (Fe_2O_3).

Iron oxide is reduced to produce iron.

Balance the equation for the reaction.

$\_\_Fe_2O_3 + \_\_C \rightarrow \_\_Fe + \_\_CO_2$

(1)

(h) Name the element used to reduce iron oxide.

____

(1)

(i) What is meant by reduction?

Tick **one** box.

Gain of iron ☐

Gain of oxide ☐

Loss of iron ☐

Loss of oxygen ☐

(1)
(Total 10 marks)

10 The flow diagram shows the main stages used to extract a metal from its ore.

mining the ore → purifying the ore → extracting the metal

The table shows some information about three metals.

Metal	Metal ore	Purified ore	% of metal in the ore	% of metal in the Earth's crust
aluminium	bauxite	aluminium oxide, Al_2O_3	28.0	8.0
copper	chalcocite	copper sulfide, Cu_2S	0.5	0.001
iron	haematite	iron oxide, Fe_2O_3	29.0	5.0

(a) Use the information in the table and your knowledge and understanding to help you to answer the questions.

(i) Suggest why purifying the copper ore produces large quantities of waste.

____

____

____

(1)

(ii) Suggest why the annual world production of iron is forty times greater than that of aluminium.

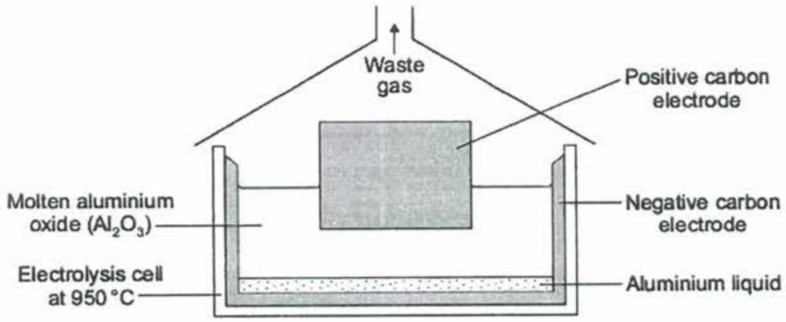
____

____

____

(1)

(b) Aluminium is used for drinks cans.
Aluminium is extracted from its purified ore by electrolysis.



(i) Suggest why the aluminium produced in the electrolysis cell is a liquid.

____

____

(1)

(ii) In this electrolysis, aluminium and oxygen gas are produced from the aluminium oxide.

Use the information in the diagram to suggest why most of the waste gas is carbon dioxide and not oxygen.

____

____

____

____

(2)

(iii) Aluminium is the most abundant metal in the Earth's crust.

Suggest **two** reasons why we should recycle aluminium drinks cans.

1. ____

____

2. ____

____

(2)
(Total 7 marks)

11 Iron is extracted from its ore.

(a) Iron ore is quarried.

Photograph supplied by Stockbyte/Thinkstock

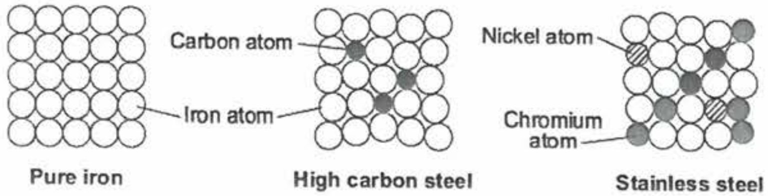
Quarrying iron ore has impacts that cause environmental problems.

Tick (✓) **two** impacts of quarrying that cause environmental problems.

Impact of quarrying	Tick (✓)
puts off tourists	
causes dust pollution	
increases jobs	
increases traffic	

(2)

(b) The diagrams represent the atoms in iron and the atoms in two alloys of iron.



Use the diagrams to help you to answer these questions.

(i) Complete the sentence.

Pure iron does **not** have many uses because ______________________

______________________ **(1)**

(ii) Stainless steel is more expensive than pure iron.

Suggest why.

____

______________________ **(1)**

(c) Draw a ring around the correct answer to complete each sentence.

(i) Pure iron is

a compound.
an element.
a mixture.

(1)

(ii) High carbon steel is used for a drill bit because it is

brittle.
easily bent.
hard.

(1)

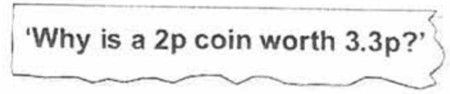
(iii) Stainless steel is used to make cutlery because it

contains three different atoms.
melts at a very high temperature.
is resistant to corrosion.

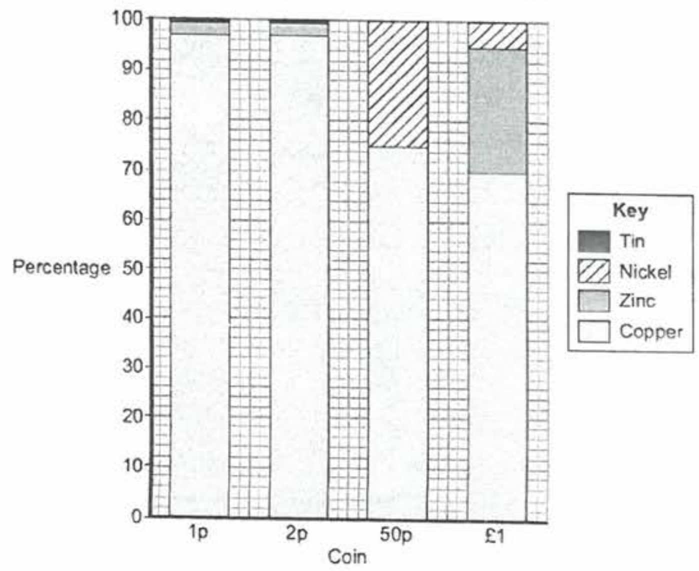
(1)

(Total 7 marks)

12 This is the headline from a newspaper:



(a) The bar chart shows the percentage of metals in UK coins in 1991.



Use the bar chart to answer these questions.

(i) Which metal is in all of these coins?

______________________ **(1)**

(ii) Which coin does **not** contain zinc?

___

(1)

(iii) What is the percentage of nickel in a 50 p coin?

Percentage = ___ %

(1)

(iv) Draw a ring around the correct metal to complete the sentence.

Pure copper is too soft to be used for 1 p and 2 p coins.

Copper is mixed with zinc and [iron / nickel / tin] for 1 p and 2 p coins.

(1)

(b) The value of the metal in 2 p coins, made in 1991, is now 3.3 p.

Suggest why a 2 p coin made in 1991 is worth 3.3 p.

___

___

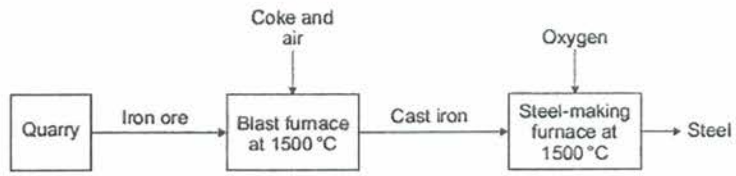
___

(1)

(Total 5 marks)

13 The iron produced from iron ore in a blast furnace is called cast iron.

Cast iron is converted into steel in a furnace.



Iron ore contains iron oxide.
Coke contains carbon.

(a) Quarrying iron ore will have an impact on everything near to the quarry.

(i) Describe **one** positive impact and **one** negative impact of quarrying iron ore.

positive impact ___

___

negative impact ___

___

(2)

(ii) Draw a ring around the correct answer to complete the sentence.

Ores contain enough metal to make extraction of the metal [carbon neutral. / economical. / reversible.]

(1)

(b) Many chemical reactions take place in a blast furnace.
Use the flow diagram to help you to answer this question.

Suggest how the blast furnace is heated.

___

___

(1)

(c) A chemical reaction for the extraction of iron is:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

(i) Complete the word equation for this chemical reaction.

__________ + carbon monoxide → iron + __________

(2)

(ii) Draw a ring around the correct answer to complete the sentence.

Iron is extracted from its ore by

decomposition.
oxidation.
reduction.

(1)

(d) Cast iron contains about 4% carbon.
Cast iron is converted into low-carbon steels.

(i) Low-carbon steel is produced by blowing oxygen into molten cast iron.

Suggest how oxygen removes most of the carbon.

____

____

____

____

(2)

(ii) Draw a ring around the correct answer to complete the sentence.

Metals, such as nickel, are added to low-carbon steels to make

the steel

corrode easily.
easy to shape.
much harder.

(1)

(e) Recycling steel uses less energy than producing steel from iron ore.

Tick (✓) **one** advantage and Tick (✓) **one** disadvantage of recycling steel.

Statement	Advantage Tick (✓)	Disadvantage Tick (✓)
Iron is the second most common metal in the Earth's crust.		
Less carbon dioxide is produced.		
More iron ore needs to be mined.		
There are different types of steel which must be sorted.		

(2)
(Total 12 marks)

14 Where copper ore has been mined there are areas of land that contain very low percentages of copper compounds.

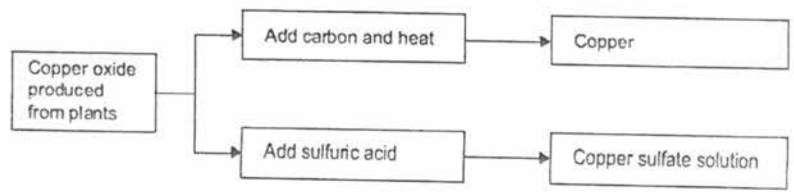
One way to extract the copper is to grow plants on the land.

The plants absorb copper compounds through their roots.

The plants are burned to produce copper oxide.

The copper oxide produced from plants can be reacted to produce copper or copper sulfate solution, as shown in **Figure 1**.

Figure 1



(a) Draw a ring around the correct answer to complete each sentence.

(i) Copper ores contain enough copper to make extraction of the metal

carbon neutral.
economical.
reversible.

(1)

(ii) Using plants to extract metals is called

photosynthesis.
phytomining.
polymerisation.

(1)

(iii) Copper oxide reacts with carbon to produce copper and

carbon dioxide.
oxygen.
sulfur dioxide.

(1)

(b) Copper is produced from copper sulfate solution by displacement using iron or by electrolysis.

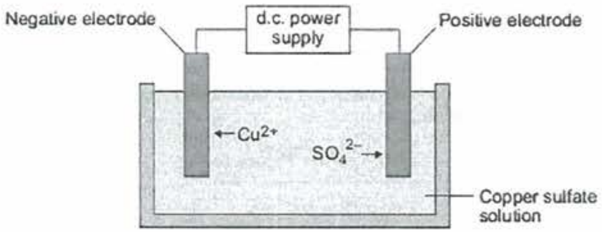
(i) Complete the word equation.

copper sulfate + iron ⟶ __________ + __________

(2)

(ii) **Figure 2** shows the electrolysis of copper sulfate solution.

Figure 2



Why do copper ions go to the negative electrode?

____

____

(1)

(c) Suggest **two** reasons why copper should **not** be disposed of in landfill sites.

____

____

____

____

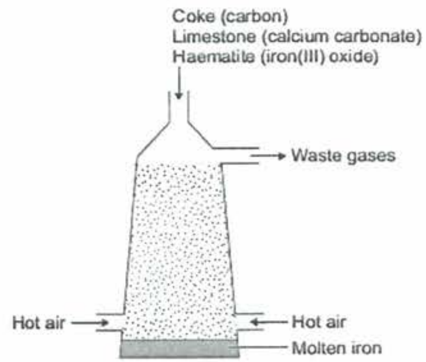
(2)

(Total 8 marks)

15 This question is about iron and aluminium.

(a) Iron is extracted in a blast furnace. **Figure 1** is a diagram of a blast furnace.

Figure 1



(i) Calcium carbonate decomposes at high temperatures.

Complete the word equation for the decomposition of calcium carbonate.

calcium carbonate ⟶ __________ + __________

(2)

(ii) Carbon burns to produce carbon dioxide.

The carbon dioxide produced reacts with more carbon to produce carbon monoxide.

Balance the equation.

$C(s) + CO_2(g) \longrightarrow$ ____ $CO(g)$

(1)

(iii) Carbon monoxide reduces iron(III) oxide:

$$Fe_2O_3(s) + 3\,CO(g) \longrightarrow 2\,Fe(s) + 3\,CO_2(g)$$

Calculate the maximum mass of iron that can be produced from 300 tonnes of iron(III) oxide.

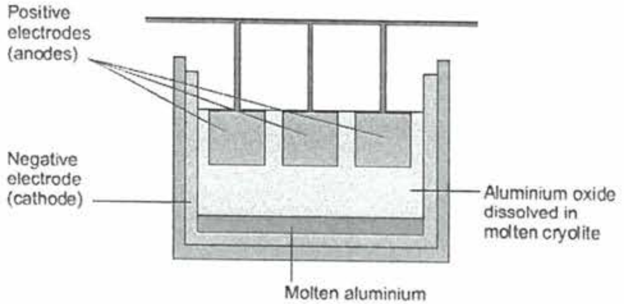
Relative atomic masses (A_r): O = 16; Fe = 56

Maximum mass = ______________ tonnes

(3)

(b) Aluminium is extracted by electrolysis, as shown in **Figure 2**.

Figure 2



(i) Why can aluminium **not** be extracted by heating aluminium oxide with carbon?

(1)

(ii) Explain why aluminium forms at the negative electrode during electrolysis.

(3)

(iii) Explain how carbon dioxide forms at the positive electrodes during electrolysis.

(3)

(Total 13 marks)

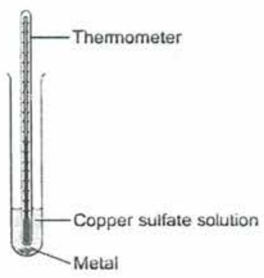
16 A student investigated displacement reactions of metals.

The student added different metals to copper sulfate solution and measured the temperature change.

The more reactive the metal is compared with copper, the bigger the temperature change.

The apparatus the student used is shown in **Figure 1**.

Figure 1



(a) State **three** variables that the student must control to make his investigation a fair test.

1. ______________________________

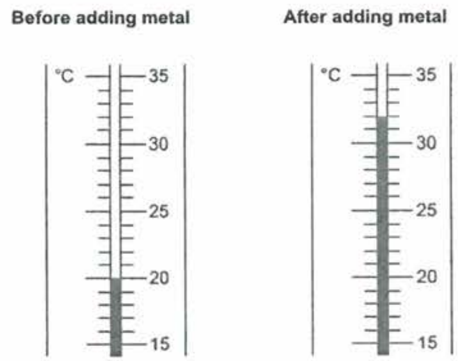
2. ______________________________

3. ______________________________

(3)

(b) **Figure 2** shows the thermometer in one experiment before and after the student added a metal to the copper sulfate solution.

Figure 2



Use **Figure 2** to complete **Table 1**.

Table 1

Temperature before adding metal in °C	______
Temperature after adding metal in °C	______
Change in temperature in °C	______

(3)

(c) The student repeated the experiment three times with each metal.

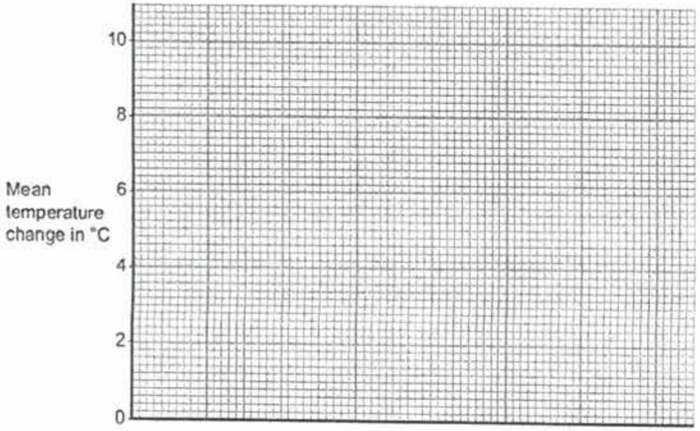
Table 2 shows the mean temperature change for each metal.

Table 2

Metal	**Mean temperature change in °C**
Cobalt	4.5
Gold	0.0
Magnesium	10.0
Nickel	3.0
Silver	0.0
Tin	1.5

(i) On **Figure 3**, draw a bar chart to show the results.

Figure 3



(3)

(ii) Why is a line graph **not** a suitable way of showing the results?

____

____

(1)

(iii) Use the results to work out which metal is the most reactive.

Give a reason for your answer.

Most reactive metal ____________________

Reason ____

____

(2)

(iv) Explain why there was no temperature change when silver metal was added to the copper sulfate solution.

____

____

____

____

(2)

(v) It is **not** possible to put all six metals in order of reactivity using these results.

Suggest how you could change the experiment to be able to put all six metals into order of reactivity.

____

____

____

____

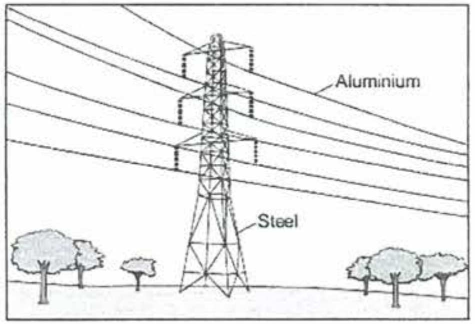
____

(2)
(Total 16 marks)

17 This question is about metals.

Figure 1 shows the metals used to make pylons and the wires of overhead cables.

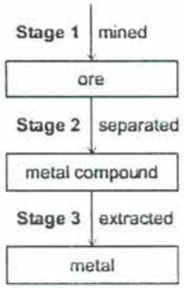
Figure 1



(a) An ore contains a metal compound.

A metal is extracted from its ore in three main stages, as shown in **Figure 2**.

Figure 2



Explain why **Stage 2** needs to be done.

____

____

____

____

(2)

(b) Cast iron from a blast furnace contains 96% iron and 4% carbon.

(i) Cast iron is not suitable for the manufacture of pylons.

Give **one** reason why.

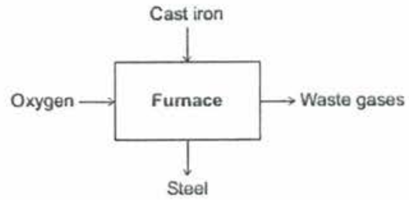
____

____

(1)

(ii) Most cast iron is converted into steel, as shown in **Figure 3**.

Figure 3



Describe how cast iron is converted into steel.

Use **Figure 3** to help you to answer this question.

____

____

____

____

(2)

(c) Aluminium and copper are good conductors of electricity.

(i) State **one** property that makes aluminium more suitable than copper for overhead cables.

____

____

(1)

(ii) How can you tell that copper is a transition metal and aluminium is **not** a transition metal from the position of each metal in the periodic table?

____

____

____

____

(2)

(iii) Copper can be extracted from solutions of copper salts by adding iron.

Explain why.

____

____

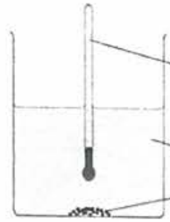
____

____

(2)
(Total 10 marks)

18 A student investigated the reactivity of different metals.

The student used the apparatus shown in the figure below.



The student used four different metals.

The student measured the temperature rise for each metal three times.

The student's results are shown in the table below.

Metal	Temperature rise in °C			Mean temperature rise in °C
	Test 1	Test 2	Test 3	
Calcium	17.8	16.9	17.5	
Iron	6.2	6.0	6.1	6.1
Magnesium	12.5	4.2	12.3	12.4
Zinc	7.8	8.0	7.6	7.8

(a) Give **two** variables the student should control so that the investigation is a fair test.

1. ____

____

2. ____

____

(2)

(b) One of the results for magnesium is anomalous.

Which result is anomalous?

Suggest **one** reason why this anomalous result was obtained.

Result ____

____

Reason ____

____

(2)

(c) Calculate the mean temperature rise for calcium.

____

Mean temperature rise = ____________ °C

(1)

(d) The temperature rose when the metals were added to sulfuric acid.

Give **one** other observation that might be made when the metal was added to sulfuric acid. How would this observation be different for the different metals?

____

____

____

____

(2)

(e) Aluminium is more reactive than iron and zinc but less reactive than calcium and magnesium.

Predict the temperature rise when aluminium is reacted with dilute hydrochloric acid.

____

Temperature rise = ____________ °C

(1)

(Total 8 marks)

Mark schemes

1 (i) idea that:
carbon is above lead in the reactivity series } NOT
for 1 mark

carbon is below aluminium in the reactivity series } OXIDE
for 1 mark

carbon can remove oxygen from/reduce lead oxide or cannot remove oxygen from aluminium oxide not aluminium more reactive than lead
for 1 mark

OR similar ideas in comparing bond strengths

3

(ii) (carbon + lead oxide) →*lead + *carbon dioxide
each for 1 mark

accept correct formulae CO_2 and CO **NOT** carbon oxide

2

[5]

2 (a) *ideas that it is a*

- compound of metal/metal oxide/combined (NOT mixed) cpd/ named cpd O^{2-}/S^{2-}/CO_3^{2-} etc
- found naturally/in rocks/in Earth's Crust
for 1 mark each

2

(b) reduction (accept smelting/refining but not electrolysis)
for 1 mark

1

(c) One example. Al or above in Reactivity Series ie Group I or II metals NOT Pb/Cu or compounds
for 1 mark

1

[4]

3 (a) (i) 5(%) 1

(ii) 0.35

$\frac{5}{10} \times 7$

for 1 mark 2

(b) (i) reduction

accept (it's) reduced

*do **not** accept redox / deoxidation* 1

(ii) heat with / reduce / react with **or** (chemical) reaction 1

with a metal / element / substance higher in reactivity

ignore displace
*accept higher named elements **or** symbol*
accept carbon monoxide / coal / coke

*correct word equation for **2** marks*
*correct formulas for **1** mark*
*correct balanced symbol equation for **2** marks* 1

or

electrolysis:
molten (1)
electrolysis (1)

[6]

4 (a) hydrogen

for 1 mark 1

(b) oxygen

for 1 mark 1

[2]

5 (a) unreactive / near bottom of reactivity series 1

(b) carbon more reactive / higher up reactivity series 1

(c) very reactive / near top of reactivity series 1

cannot use displacement methods / can only be extracted by electrolysis / had to wait discovery of electricity 1

[4]

6 (a) An arrow indicating a position between aluminium and zinc. 1

(b) electrolysis 1

because calcium is more reactive (than aluminium **or** carbon)

accept it is more reactive
***or** very reactive* 1

OR

in a blast furnace 1

because calcium is less reactive (than carbon **or** lower) 1

(c) any equation from

1 mark for correct formulae
1 mark for balancing

$2ZnO + C \rightarrow 2Zn + CO_2$

$ZnO + CO \rightarrow Zn + CO_2$

$ZnO + C \rightarrow Zn + CO$ 1

[5]

7 (a) (very) small percentage / amount (in the Earth's crust)

any indication that there is a small amount, eg not much (left)
accept rare (elements) / rarer
accept not commonly found
ignore cannot find easily
ignore hard to extract 1

(b) (i) oxygen / O_2 / O

*do **not** accept O^2* 1

(ii) any **one** from:

- potassium / K
- sodium / Na
- calcium / Ca
- magnesium / Mg

symbols must be correct
write name and incorrect symbol,
ignore symbol 1

(c) (i) heating (with) **or** hot air blown into furnace

accept high temperatures or (very) hot 1

carbon / carbon monoxide / coke / coking coal

*do **not** accept coal / charcoal accept balanced equation only*

or

carbon reacts with O_2 **or** carbon / coke burning (1)

accept balanced equation only CO / CO_2

CO reacts with the ore (1)

for naming the reducing agent 1

(ii) cost of melting ore / electricity
makes aluminium expensive (owtte)
or (large amount of) electricity used
or because you have to use electrolysis
or aluminium is higher in the reactivity series
or aluminium is harder to reduce
or unable to reduce with carbon
or the cost of purifying the bauxite

*do **not** accept harder to extract / produce*
*more energy is **not** enough* 1

[6]

8 (a) lead oxide + carbon = lead + carbon dioxide
(A symbol equation was accepted if correct) 1

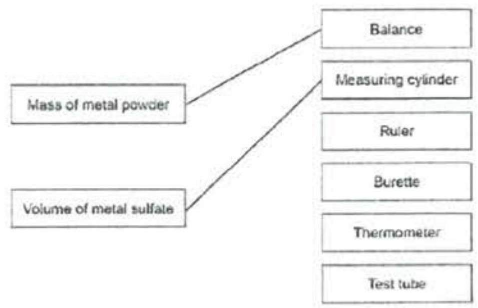
(b) oxygen removed (or addition of electrons) 1

[2]

9 (a) Whether there was a reaction or not 1

(b) brown / orange / dark deposit on zinc
or
blue solution turns colourless / paler 1

(c) **Variable** **Measuring instrument**



more than one line drawn from a variable negates the mark 2

(d) (Most reactive) **Magnesium**
Zinc
(Least reactive) **Copper**

must all be correct 1

(e) would not be safe **or**

too reactive

allow too dangerous 1

(f) Gold 1

(g) $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

allow multiples 1

(h) carbon 1

(i) Loss of oxygen 1

[10]

10 (a) (i) low percentage / very little of metal (in the ore)

accept only 0.5% metal in the ore **or** *over 99% waste in the ore* **or** *nearly 100% waste in the ore*

ignore reference to percentage of metal in the Earth's crust **or** *energy used or pollution*

1

(ii) any **one** from

(it = iron)

- iron uses less energy / fuel for extraction
  ignore electrolysis / uses electricity / reactivity
- iron has more uses
- more demand for iron
  ignore high abundance in the Earth's crust / high percentage of metal in ore
- iron is stronger
  ignore harder
- cheaper / costs less
- easier to extract

1

(b) (i) has melting point lower than 950°C

(it = aluminium)

allow has a low melting point

ignore boiling point

1

(ii) electrode(s) made of carbon

1

oxygen reacts with electrode(s) / carbon

accept $C + O_2 (\rightarrow CO_2)$

NB oxygen reacts with the carbon electrode(s) = **2** *marks*

1

(iii) any **two** from:

- saves resources / non-renewable
  accept aluminium / ore will run out **or** *conserves aluminium*
- landfill problem
  accept aluminium does not corrode
- saves energy / fuel / electricity
  ignore global warming
- less carbon dioxide / carbon emissions **or** reduces carbon footprint
  ignore consequences of quarrying / mining
- less quarrying / mining
  ignore pollution / harms environment / costs / easy to recycle

2

[7]

11 (a) causes dust pollution

1

increases traffic

1

(b) (i) it is soft

accept the layers of atoms can slide over each other

ignore other properties

1

(ii) contains chromium / nickel

allow contains other metals

1

(c) (i) an element

1

(ii) hard

1

(iii) is resistant to corrosion

1

[7]

12 (a) (i) copper / Cu

1

(ii) 50 (p)

1

(iii) 25

1

(iv) tin

1

(b) any **one** form:

- high cost of <u>copper</u>

  allow <u>metal</u> is expensive
- less copper available **or** (copper ores exhausted / **only** low-grade ores available)

  allow <u>copper</u> is non-renewable
- high demand for copper
- high percentage (%) of copper in the coin
- inflation (of cost)

1

[5]

13 (a) (i) Positive impact

any **one** from:

- provides employment **or**
- improves local economy
- improved transport - new roads are built, new rail links
- after use the quarry could provide recreation facilities

1

Negative impact

any **one** from:

- destruction of animal habitats
- fewer plants and trees to absorb carbon dioxide
- visual pollution **or** noise pollution **or** atmospheric / air pollution

  allow dust pollution
- more traffic
- uses non-renewable resources

  allow pollutants from burning diesel

1

(ii) economical

1

(b) carbon / coke burns (in oxygen / air)

accept carbon / coke reacts with oxygen / air

1

(c) (i) iron oxide (reactant)

must be words

1

carbon dioxide (product)

1

(ii) reduction

1

(d) (i) oxygen <u>reacts with</u> carbon

1

or

oxygen and carbon produce carbon dioxide / carbon monoxide

carbon dioxide / carbon monoxide is a <u>gas</u>

or

the carbon is removed as a <u>gas</u>

1

(ii) much harder

1

(e) Advantage:

less carbon dioxide is produced

1

Disadvantage:

there are different types of steel which must be sorted

1

[12]

14 (a) (i) economical

1

(ii) phytomining

1

(iii) carbon dioxide

1

(b) (i) copper / Cu

1

iron sulfate / $FeSO_4$

1

(ii) copper / ions have a positive charge

it = copper ions

allow copper ions have a different charge

accept copper / ions are free to move

accept to gain electrons

*accept copper / ions are attracted to the negative electrode **or** opposite charges attract*

1

(c) any **two** from:

ignore not biodegradable or does not decay

- copper ores are limited / running out
  allow copper is running out
- copper can be recycled
- copper can be reused
- copper is expensive
- landfill sites are filling up
- copper compounds are toxic
  allow copper is toxic

2

[8]

15 (a) (i) calcium oxide

in either order

1

carbon dioxide

accept correct formulae

1

(ii) $C(s) + CO_2(g) \rightarrow \mathbf{2}CO(g)$

allow multiples

1

(iii) 210 (tonnes)

*award **3** marks for the correct answer with or without working*

allow ecf for arithmetical errors

*if answer incorrect allow up to **2** marks for any of the steps below:*

160 → 112

300 → 112 / 160 × 300

or

moles Fe_2O_3 = 1.875 (× 10^6) or 300 / 160

moles of Fe = 3.75 (× 10^6) or 2 × moles Fe_2O_3

mass Fe = moles Fe × 56

105 (tonnes) scores 2 (missing 1:2 ratio)

420 (tonnes) scores 2 – taken M_r of iron as 112

3

(b) (i) aluminium is more reactive than carbon **or** carbon is less reactive than aluminium

must have a comparison of reactivity of carbon and aluminium

accept comparison of position in reactivity series.

1

(ii) (because) aluminium ions are positive

ignore aluminium is positive

1

and are attracted / move / go to the negative electrode / cathode

1

where they gain electrons / are reduced / $Al^{3+} + 3e^- \rightarrow Al$

accept equation or statements involving the wrong number of electrons.

1

(iii) (because) the anodes **or** (positive) electrodes are made of carbon / graphite

1

oxygen is produced (at anode)

1

which reacts with the electrodes / anodes

*do **not** accept any reference to the anodes reacting with oxygen from the air*

*equation $C + O_2 \longrightarrow CO_2$ gains **1** mark (M3)*

1

[13]

16 (a) any **three** from:

- concentration of (salt) solution
- volume of (salt) solution
  ignore amount of solution
- **initial** temperature (of the solution)
  ignore room temperature
- surface area / form of metal
- moles of metal
  allow mass / amount
  ignore time
  ignore size of tube

3

(b) 20

1

32

1

12

allow ecf

1

(c) (i) four bars of correct height

tolerance is + / - half square

*3 correct for **1** mark*

2

bars labelled

1

(ii) *one variable* is non-continuous / categoric

accept qualitative or discrete

accept no values between the metals

1

(iii) magnesium

1

because biggest temperature change

accept gives out most energy

ignore rate of reaction

dependent on first mark

1

(iv) does not react / silver cannot displace copper

1

because silver not more reactive (than copper) **or** silver below copper in reactivity series

*do **not** accept silver is less reactive than copper sulfate*

1

(v) replace the copper sulfate

could be implied

1

with any compound of a named metal less reactive than copper

allow students to score even if use an insoluble salt

1

[16]

17 (a) The ore is not pure or contains impurities or the ore does not contain 100% of the metal compound

allow to concentrate the metal or metal compound

1

rock / other compounds need to be removed / separated

1

(b) (i) (cast iron is) brittle

allow not strong

ignore weak

1

(ii) the oxygen reacts with carbon

allow carbon burns in oxygen or is oxidised

1

reducing the percentage of carbon in the mixture
or producing carbon dioxide

1

(c) (i) aluminium has a low density

1

(ii) (because copper) is in the central / middle (block of the periodic table)

1

whereas aluminium is in Group 3 (of the periodic table)

1

(iii) iron is more reactive (than copper)

ignore cost

1

so copper is displaced / reduced

1

[10]

18 (a) any **two** from:

- concentration / volume of dilute hydrochloric acid
- mass of metal powder
- surface area of metal powder
- stirring (of any) / rate of stirring

allow reacted for the same length of time

2

(b) 4.2 °C

allow Magnesium Test 2

1

and any **one** from:

- lower mass of magnesium added
- surface area of magnesium too low
- magnesium coated in magnesium oxide (so took a while to start reacting)
- not stirred
- not stirred as quickly as the other metals
- not reacted for as long a time as the other metals

allow reason for break in circuit

1

(c) 17.4(°C) 1

(d) bubbles of gas 1

more (bubbles) seen with calcium than other metals

allow any correct comparison between two metals 1

(e) any value between 7.9 °C and 12.3 °C 1

[8]

Examiner reports

1 Most candidates incorrectly compared the reactivity of lead with aluminium rather than lead with carbon and then carbon with aluminium.

Most candidates correctly completed the equation but some lost marks by giving carbon oxide.

2 **Paper I4**

This question was poorly answered. Most candidates found it difficult to describe an ore. The few good answers noted that it was a compound of a metal found naturally in rocks. Many candidates incorrectly thought that the removal of oxygen was oxidation rather than reduction. Whilst in (c) most candidates gave either lead or iron rather than a reactive metal like aluminium or sodium.

Paper H6

(a) Full marks were surprisingly seldom gained for this seemingly simple item. Relatively few candidates referred to the metals in ores being combined with other elements as compounds.

(b) "Reduction" was the response of a disappointingly small proportion of candidates; "oxidation" or "de-oxidation" were common responses.

(c) Many candidates suggested copper or iron as metals which could not be extracted from their ores using carbon.

3 **Foundation Tier**

(a) Most candidates completed part (i) correctly but many found difficulty with part (ii). A number of candidates gave no working for part (ii), which was fine if they have the correct answer but meant that they gained no marks if they made a calculation error.

(b) (i) A surprising number of candidates gave oxidation rather than reduction for this question. A number of candidates gave de-oxidation.

(ii) Candidates often found this part quite difficult. Some candidates lost the second mark because they gave an answer such as 'add carbon to zinc oxide'. They were required to indicate that a reaction between carbon and zinc oxide is needed. Thus answers such as 'react / heat zinc oxide with carbon' would gain both marks. A large number of candidates thought that zinc could be made by simply heating zinc oxide and gained no marks.

Higher Tier

This question was very well answered by the candidates and allowed them to gain in confidence. The majority of candidates scored full marks.

(a) These calculations were done well by the candidates.

(b) (i) A fair number of candidates thought that removal of oxygen was oxidation. 'Redox' did not receive credit.

(ii) This part was usually very well answered, and most candidates were able to name a suitable reagent. A significant minority simply said that this reagent was to be 'used with', 'mixed with' or 'added to' zinc oxide, rather than stating 'react with' or 'heat with'.

4 Only better candidates were able to consistently select correct answers. Other attempts appeared to be guesswork.

5 Most candidates showed a good understanding of the Reactivity Series in parts (a) and (b). Although many mentioned electrolysis in (c), they did not always link it to the high reactivity of sodium.

6 Because of the error in the direction of the arrow in the reactivity series, parts (a) and (e) were declared void and were not marked. The arrow of increasing reactivity being reversed did not seem to disadvantage any candidate. From the (correct) responses to answers, many candidates probably did not realise the arrow was the wrong way. They were given credit for answers to other parts of the question based on logical deductions from the given information, as well as correct chemistry.

7 Part (a) was very well answered. In part (b), very few candidates identified that oxygen is removed during reduction. Part (b)(ii) was often answered correctly even when part (b)(i) was incorrect. A common incorrect answer was carbon.

A fair number of candidates gained a mark in part (c)(i) for the idea of heating the iron ore but few correctly identified the reducing agent. Part (c)(ii) was not well answered, despite the hint in the stem of the question. A simple answer such as the cost of the electricity was all that was required.

10 (a) (i) Many suggestions were incorrectly linked to the amount of copper metal in the Earth's crust; however, several candidates understood that there was very little metal available in the copper ore. A few candidates were more concerned with pollution caused by the waste gases produced from copper sulfide, and made reference to sulfur dioxide and acid rain.

(ii) There was a wide variety of correct suggestions with most candidates stating that iron is 'more useful', 'more in demand', 'cheaper' or 'stronger'. A few candidates correctly stated that iron is 'easier to extract'. However, candidates should be advised to be precise and not to write vague statements, such as, 'easier to get'.

(b) (i) Far too many candidates just stated that it turned into a liquid because 'it is hot' or 'at 950°C'. This was just restating the information in the question. The best answers came from candidates who appreciated that they had to compare the temperature of the electrolysis cell to the melting point of aluminium. Candidates were awarded the mark for suggesting that the aluminium 'melts' or that the temperature in the cell is either at or above the melting point of aluminium. Marks were consistently lost for answers that were otherwise good but where candidates referred to boiling point rather than melting point, for example, 'aluminium has a low boiling point so it melts'.

(ii) This question was poorly answered by candidates. Very few candidates gained two marks for realising that the 'electrode(s) are made of carbon' and that 'carbon reacts with oxygen' to produce carbon dioxide. Most candidates who managed to gain a mark here got it for mentioning that the 'electrode(s) are made of carbon'. There were several common incorrect ideas, these included 'aluminium burns to give off carbon dioxide', 'oxygen burns to form carbon dioxide', 'carbon dioxide is released because of heating' and 'we use up oxygen when we breathe in and breathe out carbon dioxide'.

(iii) The reasons for recycling appeared to be well understood. Most candidates gained at least one mark usually for 'saves resources or aluminium is non-renewable'. There were too many vague answers including 'to save money', 'to reuse', 'less pollution' and 'good for the environment'.

11 (a) The majority of students achieved full marks for identifying the two environmental impacts of quarrying iron ore.

(b) (i) Very few students achieved the mark because they did not know that pure iron is too soft to have many uses. Many gave answers related to pure – 'it only contains iron atoms' or gave incorrect physical properties such as, 'it is a good conductor of heat/electricity' and 'it has a high melting/boiling point'.

(ii) Many students correctly suggested that stainless steel is more expensive than pure iron because other metals, chromium and nickel, are used in stainless steel.

(c) (i) Most students gained the mark for knowing that pure iron is an element.

(ii) A large majority of students understood that high carbon steel must be hard to be used as a drill bit.

(iii) Most students knew that stainless steel is used to make cutlery because it is resistant to corrosion.

12 (a) (i) The majority of students achieved the mark for identifying the metal in all of the coins.

(ii) The majority of students achieved the mark for identifying that zinc is not in the 50p coin.

(iii) Most students used the bar chart to work out that there is 25% nickel in a 50p coin.

(iv) Most answers were correct, stating that copper, zinc and tin were used in 1p and 2p coins.

(b) Most students were unable to gain the mark because they could not give a clear reason why a 2p coin made in 1991 is now worth 3.3p.

13 (a) (i) Most students gained at least one mark. The most common correct answers were 'provides jobs' and a 'specified type of pollution'. There were a number of vague answers that did not describe the impacts and just stated 'pollution' or 'carbon dioxide produced' or 'non-renewable'. A number of students also referred to the process of producing iron or steel instead of the quarrying of iron ore.

(ii) Few students knew that ores contain enough metal to make extraction of the metal economic.

(b) Surprisingly poorly answered because most students thought that 'by coke' or by 'coke and air' were sufficient for the answer. There were a range of interesting responses that did not gain credit such as, the blast furnace is heated by 'the Sun', 'a bunsen burner', 'hot air', 'a flame', 'fire' and 'electrolysis'. Although many students mentioned coke and air, they did not state they react just that they are added. Several students did not mention coke but suggested other fuels such as coal or natural gas as being used to heat the blast furnace.

(c) (i) Many correct answers were given but it is surprising that a significant number of students still could not name iron oxide calling it iron ore and carbon dioxide was often called 'carbonate', 'cobalt' or 'carbon monoxide'.

(ii) Few students understood that iron is extracted from its ore by reduction.

(d) (i) Very few students gained any marks. The most common incorrect idea was that oxygen is stronger so it pushes or blows the carbon out. Most students who got one mark did so for knowing that carbon dioxide is produced. Other incorrect suggestions were that oxygen is more reactive than carbon so removes it by decomposition or by neutralisation or by reduction.

(ii) Most students knew that metals, such as nickel, are added to low-carbon steels to make the steel much harder.

(e) Most students gained at least one mark. The most common correct answer was the advantage that less carbon dioxide is produced. Several students thought that four ticks were needed, that is, one in each row. Many incorrectly thought that the disadvantage was more iron needs to be mined.

14 (a) (i) This part was poorly answered. Most students did not appear to understand that metal ores need to contain enough metal to make extraction of the metal economical.

(ii) Most students achieved the mark for knowing that using plants to extract metals is called phytomining.

(iii) Only a slight majority of students were able to apply their knowledge and correctly choose carbon dioxide as the other product when copper oxide reacts with carbon.

(b) (i) Most students gained one of the two marks for naming the products when copper sulfate reacts with iron. Several gained one mark because they wrote the products as 'copper' + 'sulfate'. The most common incorrect products were carbon dioxide, sulfur dioxide and water. Many students just wrote the names of the reactants in the spaces for the products.

(ii) Most students gained the mark usually for stating that copper ions have a positive charge or that copper ions are attracted to the negative electrode. The most common confused answers were that 'copper ions are negative' or 'copper is a positive electrode so is attracted to the negative electrode'. Some stated that copper ions go to the negative electrode because 'copper is magnetic'.

(c) This was poorly answered. The most common mark for this question was zero. Two common misconceptions about why copper should not be disposed of in landfill sites were that 'copper is harmful because it is reactive' and 'copper is dangerous because it conducts electricity'. The few that gained marks did so by writing about recycling copper, reusing copper, copper is running out or that copper is expensive. One problem was that many of these students do not understand the difference between recycling and reusing.

15 (a) (i) This question was well answered although some students made substances from elements that are not contained in calcium carbonate.

(ii) Almost all students gained this mark. However, a few students added an additional "2" before the carbon or changed the formulae of some of the substances.

(iii) Many fully correct answers were seen to this question. Common errors included excessive rounding or missing the ratio of iron(III) oxide to iron in the equation. As in question 7(e), incorrect answers accompanied by a jumble of random and incorrect working could not be credited but the inclusion of some words in working to say what the numbers represent may make it possible to award marks.

(b) (i) This was well answered. Although most students gave clear answers comparing the reactivity of carbon and aluminium, a few gave answers such as "aluminium is not less reactive than carbon", which while correct is not the simplest way of expressing the idea. A small number of students used phrases such as "it is more reactive than it" - students should be encouraged to write the correct name rather than "it" as this will help make their meaning clear.

(ii) While many excellent answers were seen, the two most common errors were not stating that aluminium ions are positive and errors or contradictions in explaining the gain of electrons being reduction (comments such as the aluminium ions gain electrons and so are oxidised are not credit worthy).

(iii) The fact that the anodes are made of carbon was known my most students, and that the anodes react with oxygen was also well known. However, the mark that was awarded least often was the one for stating that oxygen is produced at the anode.

16 (a) The most common error was to refer to the 'amount' of copper sulfate solution rather than specifically mention concentration or volume. A few students wanted to control the dependent variable by keeping the temperature constant or the independent variable by not changing the metal used.

(b) This was very well answered, with few errors. A very small minority of students transposed digits when calculating the difference.

(c) (i) Most students gained full marks on this question part. The most common error was to have the bar for cobalt at 5 rather than 4.5 or that for tin at 0.5 rather than 1.5. It should be noted that there is no need for students to spend time shading the bars in: a label for each bar will suffice.

(ii) Some students made excellent use of the terms categoric and non-continuous, and clearly knew when a line graph was appropriate. However, a significant number thought that a line graph could not be used either because some of the temperature changes were zero or because there was no pattern to the data.

(iii) This was very well answered.

(iv) Most students scored 1 mark by stating there was no reaction, but many did not then go on to explain why there was no reaction. In questions that ask students to explain ideas must be linked together in order to gain full marks.

(v) Most students realised the problem was the copper sulfate solution and that this needed to be replaced. However, some answers were then vague, just stating use a salt of a metal less reactive than copper, without naming one. The information in the question shows that both silver and gold are less reactive than copper, so a salt of either of these metals would have been suitable.

17 (a) This question required students to study a flow diagram and explain why a metal compound had to be separated from its ore. Most students gained just one mark for stating that the ore contained impurities or that waste materials needed to be removed. Some students confused the separation in stage 2 with the extraction in stage 3, stating that this stage was needed to extract the metal from the ore.

(b) (i) This question was not well answered. Students needed to state that cast iron is brittle, although 'not strong' was an acceptable response. Some students referred to other properties of iron such as conductivity or rusting, which was not the specific property relating to the question, and did not gain credit.

(ii) Again this question was not well answered. Students needed to study a flow diagram showing how cast iron is converted to steel. The percentage of carbon in cast iron was given in the stem of the question. Some students just described the flow chart, and gained no credit. One mark was for stating that oxygen reacted with the carbon, the other mark for stating that the percentage of carbon was reduced or that carbon dioxide was produced. Many students gained one mark for stating carbon dioxide was formed. Some students gave erroneous answers relating to the formation of alloys and not how cast iron is converted to steel.

(c) (i) This question was poorly answered. The question required the property of aluminium to be stated, namely low density. The consequence of low density being light, lightweight or lighter is true, but was not creditworthy.

(ii) There were many acceptable phrases to describe the position of copper or a transition metal in the periodic table; these were 'central block', 'middle block', 'between Group 2 and 3' or 'not in a group'. Students were expected to state that aluminium is in Group 3; or 'aluminium is in the same group as Boron' was an acceptable alternative as to why aluminium is not a transition metal. Many students gained both marks.

(iii) Many students knew that iron is more reactive than copper. However, a significant number of students knew that there was a displacement reaction but were not sure what displaced what. Also some students used the word 'it' and it was difficult to know whether 'it' was iron or copper being displaced. Students need to clearly state which metal is displacing which metal in a displacement question. A number of students just stated that iron reacted with the salts to give copper, which was not creditworthy.