8.2 – THE CHEMICAL EARTH

1 – The living and non-living components of the Earth contain mixtures

1.1 Construct word and balanced formulae equations of chemical reactions as they are encountered

- To make **word equations**, write each chemical formula, in words. Then, add in pluses and arrows.

$$magnesium + oxygen \rightarrow magnesium\ oxide$$

- To create **balanced formulae equations**, write down **chemical symbols** (see 1.7), their **state of matter** and **balance** the equation.

Magnesium + Oxygen → Magnesium Oxide	The original word equation.
$Mg + O_2 \rightarrow MgO$	There are not enough Oxygen atoms on the right.
$Mg + O_2 \rightarrow 2MgO$	Double the **whole molecule**, not just magnesium. There are not enough magnesium atoms now.
$2Mg + O_2 \rightarrow 2MgO$	Add a 2 in front of magnesium on the left. Now, LHS = RHS
$2Mg_{(s)} + O_{2\ (g)} \rightarrow 2MgO_{(s)}$	Place the states of matter for each substance.

- Combustion – $\boldsymbol{Fuel + Oxygen \rightarrow Carbon\ dioxide + Water}$, example: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- Corrosion – $\boldsymbol{Metal + Oxygen \rightarrow Metal\ Oxide}$, example: $2Cu + O_2 \rightarrow 2CuO$
- Respiration – $\boldsymbol{Glucose + Oxygen \rightarrow Carbon\ Dioxide + Water}$, example: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Precipitation – $\boldsymbol{Soluble\ salt + Soluble\ salt \rightarrow Insoluble\ salt + Soluble\ salt}$
  - Example: $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$ ($Cu(OH)_2$ is insoluble)
- Neutralisation - $\boldsymbol{Acid + Base \rightarrow Salt + Water}$, example: $HCl + NaOH \rightarrow NaCl + H_2O$
- Acids on metals – $\boldsymbol{Metal + Acid \rightarrow Salt + Hydrogen}$**,** example: $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
- Acid on metal *oxide* – $\boldsymbol{Metal\ Oxide + Acid \rightarrow Salt + Water}$**,** example: $MgO + 2HCl \rightarrow MgCl_2 + H_2O$
- Acids on carbonates – $\boldsymbol{Carbonate + Acid \rightarrow Salt + Water + Carbon\ Dioxide}$
  - Example: $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$
- Decomposition – $\boldsymbol{Molecule \rightarrow Molecule\ part + Molecule\ part}$, example: $2H_2O \rightarrow 2H_2 + O_2$

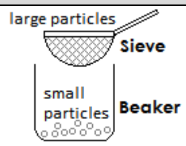
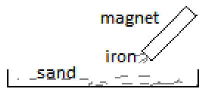
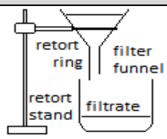
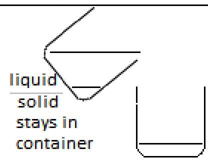
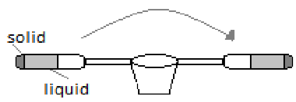
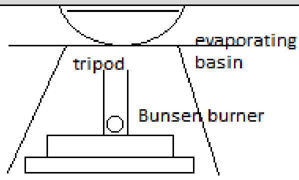
1.2 Identify the difference between elements, compounds and mixtures in terms of particle theory

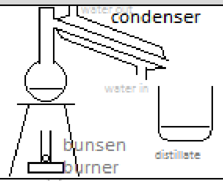
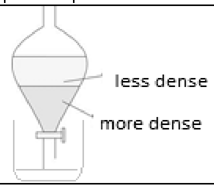
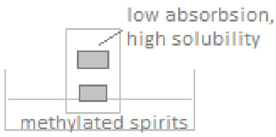
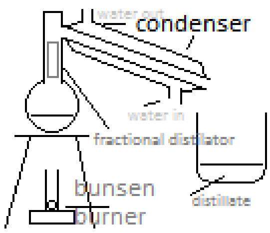
- Particle theory helps us **visualise** differences between elements, compounds and mixtures.
- **Elements** are basic building blocks, having own unique symbol and physical and chemical properties.
- **Compounds** are **two or more particles** chemically bonded.
- A **mixture** is composed of a mix of **elements and compounds**, e.g. a solution.
  - Can be separated using simple separation techniques, does not have fixed properties.

1.3 Identify that the biosphere, lithosphere, hydrosphere and atmosphere contain examples of mixtures of elements and compounds

- **Biosphere** – region of Earth containing living organisms
  - Mixtures: carbon-containing compounds, carbohydrates, protein fats and vitamins, free elements (extremely rare)
  - Most abundant elements: oxygen (60%), carbon (21%), hydrogen (11%)
  - Examples: wood, manure, blood, sugar cane
- **Lithosphere** - outer rocky layer, which includes crust and upper rigid part of mantle
  - Mixtures: rocks, sand, soils, mineral ores, coal, oil and natural gas
  - Most abundant elements in Earth's crust: oxygen (46.6%), silicon (27.7%)
  - Most abundant elements in whole earth: iron (35%), oxygen (30%)
  - Examples: metal ores, sandstone, granite
- **Hydrosphere** - zone containing liquid water, water vapour and ice
  - Mixtures: Predominately water, oxygen, nitrogen and compounds dissolved in it
  - Most abundant elements: oxygen (86%), hydrogen (10.8%)
  - Examples: salt water
- **Atmosphere** - low-density gaseous layer which extends from surface to the edge of space
  - Mixtures: mainly gases – nitrogen (78%), oxygen (21%), argon (1%)

1.4 Identify and describe procedures that can be used to separate naturally occurring mixtures of:

Technique (Identify)	Procedure (Describe)	Diagram
Solids of different sizes		
Sieving	Properties: Different **size particles**, larger is trapped in sieve while smaller falls through sieve	
Magnetism	Properties: One substance **magnetically attracted** and the other is not, due to attracting substance goes to magnet	
Solids and Liquids		
Filtration	Properties: solubility and different **size of particles**, solid can be dissolved into liquid and filtered as it is small	
Decanting	Properties: different **densities**, heavier substance settles blow and causes lighter substance to be on top	
Centrifuging	Properties: different **densities**, causes heavier substance to settle outside of container where they are collected	
Dissolved solids in liquids		
Evaporation and crystallisation	Properties: different **boiling points**, lower boiling point substance evaporates and other crystallises	

Liquids		
Distillation	Properties: different **boiling points**, lower boiling point substance evaporates then condenses into the condenser and is called a distillate	
Separation Funnel (insoluble liquids with different densities)	Properties: different **densities**, denser liquid leaves funnel at bottom when tap is opened, lighter is left in funnel when tap is closed	
Chromatography	Properties: different rates of **absorption** and **solubility**, lower absorption and higher solubility means faster up the paper	
Fractional Distillation	Properties: significant difference but similar **boiling points**, both liquids boil and move up the distillation column and substances recondense and are collected	
Gases		
Liquefaction then fractional distillation	Properties: different **boiling points**, liquid nitrogen used to lower temperature to liquefy gas, then fractional distillation occurs when heated	

1.5 Assess separation techniques for their suitability in separating examples of earth materials, identifying the differences in properties which enable these separations

Technique	Difference in properties (Identify)
Solids of different sizes	
Sieving	Size of particles
Magnetism	Magnetic attractions (one is, one isn't)
Solids and Liquids	
Filtration	Size of particles
Decanting	Densities
Centrifuging	Densities
Dissolved solids in liquids	
Evaporation and crystallisation	Boiling points
Liquids	
Distillation	Boiling points
Separation Funnel	Densities
Chromatography	Rates of absorption and solubility
Fractional Distillation	Significant difference but similar boiling points
Gases	
Liquefaction then fractional distillation	Different boiling points

1.6 Describe situations in which gravimetric analysis supplies useful data for chemists and other scientists

- **Gravimetric analysis** measures the **proportion of each component** in a mixture and expresses it as a **weight percentage**.
- A mining company may want to know the **composition of a particular ore sample** to see if it is **financially viable** to mine the ore body.
- A health authority may want to know the **composition of the air** to see if it **pollutes** a site.
- A food company want to know the amount of **fibre in a batch of fruit** to provide information to customers.

1.7 Apply systematic naming of inorganic compounds as they are introduced in the laboratory

- For **metals and non-metals**, name the **metal first** and the second non-metal with the name ending with -**ide**.
- For **two non-metals**, name the **first non-metal** and then the **second non-metal**, with a **prefix**. If the first non-metal has **more than one atom**, add a **prefix**.
    - First element named is the one that occurs further to the left of the Periodic Table. If both are in the same group the one lower down is named first. (Exception: oxygen is named last in compounds with Cl, Br and I)
- For **two metals**, name **the metal** (with roman numerals) and then **the complex compound**.
- Complex ions (polyatomic ions):

-1		-2		-3	
hydroxide	OH	carbonate	CO_3	phosphate	PO_4
nitrate	NO_3	sulfate	SO_4		
nitrite	NO_2	sulfite	SO_3		
bicarbonate	HCO_3	chromate	CrO_4	+1	
Acetate	CH_3COO			ammonium	NH_4
Cyanide	CN				
Chlorate	ClO_3				

If a transitional metal does not have a Roman numeral, its valency is +2 (except gold and silver = -1)

1.8 Identify IUPAC names for carbon compounds as they are encountered

- Hydrocarbons with single bonds are called alkanes, double bonds are called alkenes and triple bonds are called alkynes.
    - Alkanes general formula: C_nH_{2n+2}
    - Alkenes general formula: C_nH_{2n}
    - Alkynes general formula: C_nH_{2n-2}

- The name for a carbon compound consists of a stem which tells us the length of the carbon chain (how many carbons) and a suffix which tells us how it is bonded.

C_1 = meth-	C_2 = eth-	C_3 = prop-	C_4 = but-	C_5 = pent-
C_6 = hex-	C_7 = hept-	C_8 = oct-	C_9 = non-	C_{10} = dec-

2 – Although most elements are found in combinations on Earth, some elements are found uncombined

2.1 Explain the relationship between the reactivity of an element and the likelihood of its existing as an uncombined element

- The **more reactive** an element is, the **less chance** there is of finding it as an uncombined element on Earth.
  - Most unreactive elements (noble gases) exist as **single atom molecules**.
  - Unreactive metals, such as Au, Ag and Pt (native metals) exist uncombined.
- Most metals are too chemically reactive to exist free in nature and are found in combination with other elements (to gain stability).

2.2 Classify elements as metals, non-metals and semi-metals according to their physical properties

Properties	Metals	Semi-metals	Non-metals
Appearance	Lustrous	Low sheen	Dull
Electrical Conductivity	High	Low (semi-conductors)	Nil (insulators)
Thermal conductivity	High	High	Low (insulators)
Malleability and ductility	High	Moderate	Nil (brittle)
Density	Generally high	Intermediate	Low
Boiling point	Generally high	Very high	Low
Strength	High	Variable	Low

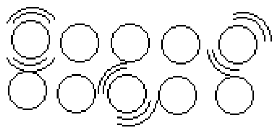
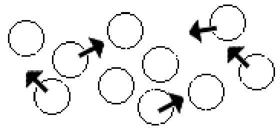
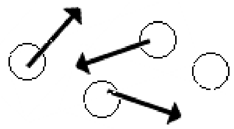
2.3 Account for the uses of metals and non-metals in terms of their physical properties

Element	Uses	Properties related to use
Copper	Electrical wiring	Ductility, high electrical conductivity
Iron	Structural building materials	High tensile strength
Zinc	Galvanising of iron	High reactivity allows it to preferentially corrode and protect the iron
Gold	Ornaments	Lustre, highly not reactive
	Jewellery	
Argon	Atmosphere for welding	Inert
	Atmosphere for metallurgy	
Helium	Meteorological balloons	Low density and lack of reactivity
Silicon	Computer chips	Semi-conductor
	Transistors	
Carbon (graphite)	Lead pencils and lubricant	Softness and layer structure
	electrodes in batteries	Conducts electricity
Carbon (diamond)	Jewellery	Transparent and has high refractive index and dispersive power
	Drill Tips	High melting point and hardness
Sulphur	Vulcanising rubber	Abundance and reactivity
	Manufacturing sulphuric acid fungicides, insecticides and hydrogen sulphite	
Phosphorus	Smoke bombs	Reactivity
	Manufacturing match leads	
Neon	Neon Lights	glow red and give out light
Chlorine	Water treatment	bactericide and algaecide
	Bleaching agent	reactivity in decolourising other chemicals

3 – Elements in Earth materials are present mostly as compounds because of interactions at the atomic level

3.1 Identify that matter is made of particles that are continuously moving and interacting

- **Matter** is composed of **atoms**. **Kinetic particle theory** – the particles of matter are continuously moving and interacting.
- **Energy of particles** controls the movement and state of the substance. **Heating** increases energy.
- **Subatomic particles** of an atom are protons, neutrons and electrons.

Properties	Solid	Liquid	Gas
Particle Location	Close together	Close together	Far apart
Movement	Vibrating in fixed position	Moving freely	Moving very freely
Diagram			
Shape	Definite shape	Depends on container	Depends on container
Volume	**Definite** volume	**Definite** volume	**Fills** all available space
Compression	**Cannot** be compressed	**Almost** incompressible	**Can** be compressed
Diffusion (spread)	Cannot diffuse	Can diffuse	Can diffuse

3.2 Describe qualitatively the energy levels of electrons in atoms

- Electrons occupy energy levels (shells) around the nucleus. They are confined to these levels and can move between them using energy.
- Each energy level has a maximum number of electrons.

Energy Level	K	L	M	N	O
Max # of electrons	2	8	18	32	50

3.3 Describe atoms in terms of mass number and atomic number

- Atoms have an equal number of positive atoms and negative atoms.
- The **atomic number** is the number of **protons** in the its atoms.
- The **mass number** is the number of **protons** plus number of **neutrons**.
- The element E can be represented by the symbol (on the right), where:
  - A = mass number
  - Z = atomic number
  - A – Z = number of neutrons

$$^{A}_{Z}E$$

3.4 Describe the formation of ions in terms of atoms gaining or losing electrons

- An **ion** is a **charged particle** formed when an atom **gains or loses** one or more electrons.
- Atoms can gain electrons by **capturing an electron** from another atom. Thus, atoms can be positive or negative.
- Atoms can also lose electrons if they are supplied with sufficient energy, where the electron can escape the attraction of the nucleus.
- Positively charged ions are called **cations**.
- Negatively charged ions are called **anions**.

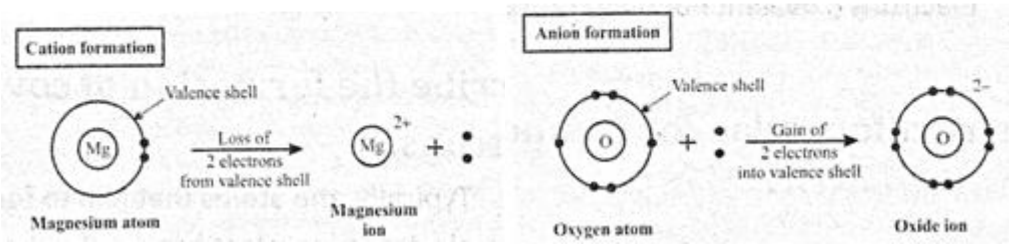
3.5 Apply the Periodic Table to predict the ions formed by atoms of metals and non-metals

- In **Groups I, II and III** (metals), cations are formed with **charges equal to their group number**.
- In **Group IV**, non-metals form **complex ions** and metals form cations with a **charge of +2 or +1**.
- In **Groups V, VI and VII** (non-metals), anions are formed with charges **equal to their group number minus 8.**
    - Group V = -3, group VI =-2, group VII = -1.
- In **Group VIII** (noble gases), they are too stable to form ions.
- Hydrogen can be an anion or a cation (H^+ and H^-).

3.6 Apply Lewis electron dot structures to:

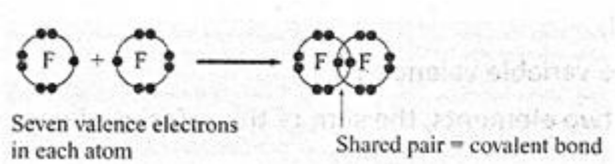
THE FORMATION OF IONS

- Only **outer shell electrons** are shown in Lewis electron dot structures.
- Elements **lose/gain** electrons and are shown in diagrams like:



THE ELECTRON SHARING IN SOME SIMPLE MOLECULES

- Elements **share** electrons and are shown in diagrams like:



- Alternatively, a circle can be drawn around the sharing electrons to represent a bond, and crosses can help differentiate from electrons from another atom.

3.7 Describe the formation of ionic compounds in terms of the attraction of ions of opposite charge

- **Ionic compounds** are formed when **metallic** elements react with **non-metallic** elements.
- Ionic bonds form when two **oppositely charged ions** (anion and cation) react.
- For example, Sodium and Chlorine react to make an ionic compound, Sodium Chloride.
    - $Na^+ + Cl^- \rightarrow NaCl$
- The **sum of valencies** should **equal to zero** (through balancing the equation).

3.8 Describe molecules as particles which can move independently of each other

- A molecule is the **smallest unit of a substance** that can **move independently**.
- It includes atoms that are held together by a **covalent bond**, as well as **monoatomic molecules** (noble gases).

3.9 Distinguish between molecules containing one atom (the noble gases) and molecules with more than one atom

- The **inert/noble gases** in Group VIII are referred to **monoatomic** (one atom) molecules.
- **Elements** that occur as gases cannot exist as single atoms, so join covalently
    - For example, elements such as Oxygen (O_2) and Hydrogen (H_2) are **diatomic molecules**.
- Some **compounds occur as molecules**, such as H_2O (water, **triatomic**) and NH_3 (ammonia, **tetra-atomic**).

3.10 Describe the formation of covalent molecules in terms of sharing of electrons

- Covalent bonds are formed between **two or more non-metallic elements**.
- Covalent molecules bond by **sharing electrons**, rather than forming ions, to stabilise their outer shell.
- For example, Hydrogen and Oxygen share their electrons to form a water molecule.
    - $2H_2 + O_2 \rightarrow 2H_2O$

3.11 Construct formulae for compounds formed from:

IONS

- When ionic compounds are formed, the **positive charges must equal to the negative charges**.
- For example, magnesium combines with chlorine:
    - The chlorine atom must be doubled to make the positive and negative charges equal.

ATOMS SHARING ELECTRONS

- In molecular compounds, the **valency of an element** is equal to the **number of electrons** that need to be **shared** to complete its valence shell.
    - For example, oxygen's valency is 2, and thus, it requires two electrons to share with (such as another oxygen or two hydrogen atoms).
- Thus, in a simple molecular compound composed of two elements, the **sum of the valencies** of one element **must match that of another**.
- The first element written should be the one that is further to the left in the periodic table or lower in a vertical group.

4 – Energy is required to extract elements from their naturally occurring sources

4.1 Identify the differences between physical and chemical change in terms of rearrangement of particles

- Physical changes do **not involve the production of new substances**, and **are reversible**.
  - Changes of state
  - Changes in physical appearance
  - Dissolving a solvent in a solute
  - Separation techniques
- Chemical changes **form one or more new chemical substances** (reactants → products) and are **difficult to reverse**.
  - Evolution of a gas
  - Formation of a precipitate on mixing solutions
  - Significant temperature change (energy lost or gained)
  - Changes in colour or odour produced
- In both reactions, mass is conserved, and particles are only **rearranged**.
  - In chemical reactions, particles are broken up and rearranged into new substances.
  - In physical reactions, particles are rearranged without changing their nature.

4.2 Summarise the differences between the boiling and electrolysis of water as an example of the difference between physical and chemical change

Electrolysis of Water	Boiling of Water
Two new substances produced – H_2 and O_2 gas	No new substances produced, change in state
Difficult to reverse	Easily reversed (cool vapour)
Requires approx. 20 – 30kJ/g	Requires approx. 2.3kJ/g
Particles broken up (H_2O molecules broken up and H_2 and O_2 molecules formed)	Does not alter particles, just separates them from one another (change in state)

4.3 Identify light, heat and electricity as the common forms of energy that may be released or absorbed during the decomposition or synthesis of substances and identify examples of these changes occurring in everyday life

- Light, heat and electricity can be released and absorbed during decomposition and synthesis.
  - **Photolysis** is the decomposition of a compound using **light energy**.
  - **Electrolysis** is the decomposition of a compound using **electrical energy**.

LIGHT

- Release of light e.g. in the combustion of magnesium.
- Absorption of light e.g. in photolysis of silver chloride.

HEAT

- Release of heat (**exothermic**) – heat is evolved – synthesis of water
- Absorption of heat (**endothermic**) – decomposition of mercury oxide

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ELECTRICAL

- Electrical energy is used to decompose chemical compounds/mixtures in various industries, e.g. decomposition of salt water to form chloride, hydrogen and sodium hydroxide.

EVERYDAY APPLICATIONS

- Decomposition reactions:

- Limestone ($CaCO_3$) is decomposed by heating to make lime, cement and glass.
- Aluminium is extracted by electrolysing molten aluminium oxide.

- Synthesis/Direct combination reactions:
  - Rusting of iron and steel to form iron (III) oxide.
  - Burning of carbon releases heat energy which we use in many ways.
  - Lighting creates a high temperature so that nitrogen and oxygen gases combine to form nitric oxide.

4.4 Explain that the amount of energy needed to separate atoms in a compound is an indication of the strength of the attraction, or bond, between them

- The stronger the chemical bonding in a compound, the more energy that is required to break the compound into elements.
- The stronger the chemical bonding in a compound, the more energy that is released when the compound is formed into its elements.
- This is because a large input of energy is necessary to break the strong bonds holding the atoms together.

5 – The properties of elements and compounds are determined by their bonding and structure

5.1 Identify differences between physical and chemical properties of elements, compounds and mixtures

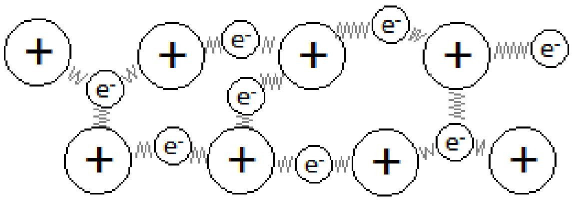
- **Physical properties** include odour, colour, taste, lustre, hardness, malleability, ductility, melting and boiling points, and solubility.
- **Chemical properties** include reactions with oxygen, water, acids and bases, and specific reactions with other substances.
- Compounds have **different properties from those of the elements that combine to form them**.
    - It also has **quite distinct properties** from a **simple mixture** of the component elements.

5.2 Describe the physical properties used to classify compounds as ionic or covalent molecular or covalent network

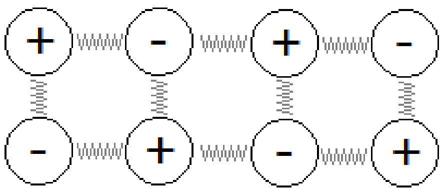
Physical Property	Metallic	Ionic	Covalent Molecular	Covalent Network
Hardness	Variable	Hard	Soft	Very Hard
Malleability/Ductility	Malleable, Ductile	Brittle	Brittle	Brittle
MP/BP	High	High	Low	Very High
Conductivity (solid)	High	Low	Low	Low
Conductivity (liquid)	High	High	Low	Low

5.3 Distinguish between metallic, ionic and covalent bonds

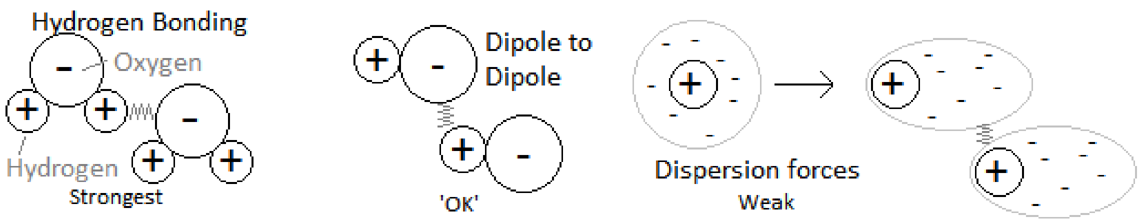
- **Metallic bonding** occurs between metals and involves the **electrostatic attraction** between **delocalised electrons** and the **metal cations**, which hold the 3D lattice together.



- **Ionic bonding** involves the **transfer of electrons** from one atom to another. The bonding consists of **electrostatic attraction** between the **positive and negative ions** formed by this transfer of electrons, which hold the 3D lattice together.
    - Examples: $CuCl_2$, MgO, NaCl

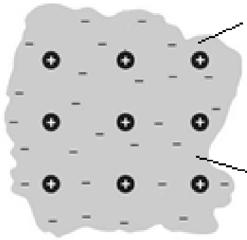


- **Covalent bonds** occur **between non-metals** and involve **intermolecular forces** holding the particles together. These forces can be **hydrogen bonding** (between H and N, O or F), **dipole to dipole** and **dispersion forces**.



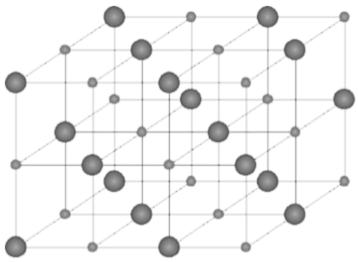
5.4 Describe metals as three-dimensional lattices of ions in a sea of electrons

- Metals **lose their outer electron shell** to become cations surrounded by a sea of **delocalised** electrons.
- The electrons **do not remain** with an individual atom.



5.5 Describe ionic compounds in terms of repeating three-dimensional lattices of ions

- Cations and anions form an array of ions **in a fixed lattice**.



5.6 Explain why the formula for an ionic compound is an empirical formula

- An empirical formula is the simplest form of a compound and represents the **simplest whole number ratio of atoms/ions** in the crystal.
- There are **no discrete molecules in ionic compounds** but an **infinite array of ions**, thus the formulae must give **the ratio** by atoms of elements **rather than the actual numbers of atoms** in a molecule.
- The **law of constant composition** states that all pure samples of the same compound contain the same elements combined together in the same proportions by mass.

5.7 Identify common elements that exist as molecules or as covalent lattices

- Elements that exist as covalent molecules include:
  - H_2, F_2, Cl_2, O_2, N_2 – diatomic gases
  - Br_2, I_2 (diatomic liquid and solid)
  - Phosphorus – P_4, Sulphur – S_8
- Elements that exist as covalent lattices include:
  - Non-metal elements such as carbon and silicon, and some compounds such as silicon dioxide.
    - Carbon (diamond) is a 3D lattice, Carbon (graphite) is a 2D lattice
  - Covalent lattices in the earth include sand, quartz, gemstones, and clays.

5.8 Explain the relationship between the properties of conductivity and hardness and the structure of ionic, covalent molecular and covalent network structures

IONIC

Property	Explanation
Hard and brittle	Any force will cause **ions of similar charge** to come closer together.
Non-conductivity of electricity when solid, but conductive when liquid or aqueous	Ions occupy fixed positions, and electrons are **strongly held by nuclei** of individual ions. When heated over melting point, **bonds are partially broken and ions become mobile**.
High melting and boiling points	Ions are **held strongly** due to **electrostatic forces**

COVALENT MOLECULAR

Property	Explanation
Soft and brittle	Forces between molecules are **weak intermolecular attractions**
Low conductivity	**Molecules are uncharged**, and **electrons are localized** in covalent bonds
Low melting and boiling points	Forces between molecules are **weak intermolecular attractions**

COVALENT NETWORK

Property	Explanation
Very hard and brittle	Atoms **strongly bound (in 3 dimensions)**, distortion breaks covalent bonds
Low conductivity	Atoms are **localized** (except graphite (2D), where electrons travel through 3^{rd} plane)
Very high melting and boiling points	**Strong covalent bonding** in three dimensions

METALLIC

Property	Explanation
Malleable and ductile, variable hardness	Ions are able to **slide over each other** when a force is applied and the **delocalised electrons are able to stabilise** the lattice during this change
High conductivity	**Delocalised electrons** move in an electrical field
High melting and boiling points	**Strong metallic bonding** exists throughout the lattice