Topic 2 – Bonding, structure, and the properties of matter

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2.1 Chemical bonds, ionic, covalent and metallic

2.1.1 Chemical bonds

(See 2.1.2-2.1.5 below)

2.1.2 Ionic bonding

Ionic bonding

- Transfer of electrons between metal & non-metal
- Electrostatic force of attraction in all directions between oppositely charged ions
- Occurs in ionic compound
- Produce giant ionic lattice

Properties of ionic compounds

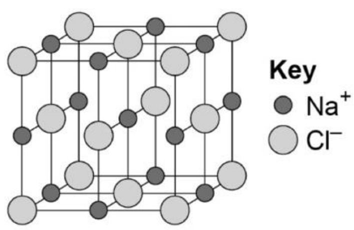
Properties	Reasons
High melting & boiling points	Requires lots of energy to break large no of strong electrostatic force of attraction between oppositely charged ions
Have regular structure (Giant ionic lattice)	Strong electrostatic force of attraction in all directions between oppositely charged ions
When melted/dissolved in water - conduct electricity	Ions are free to move & so charge can flow
When solid - doesn't conduct electricity	Ions in fixed positions

Ways of showing ionic bonding & limitations

Dot & cross diagram

Advantages	Disadvantages
• Useful for illustrating transfer of electron • Indicates from which atom the bonding electrons come from	• X illustrate 3D arrangements of atoms & electron shells • X indicate relative sizes of atoms

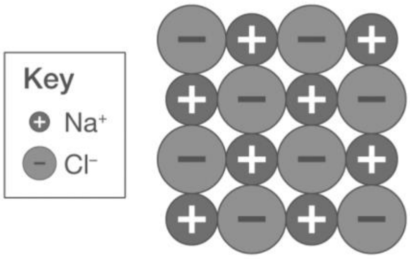
Ball and stick model



Advantages	Disadvantages

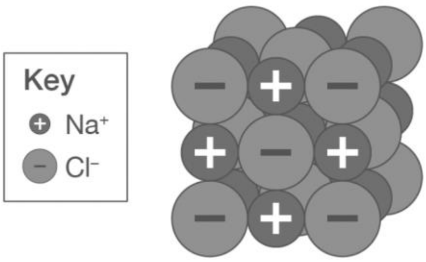
• Useful for illustrating 3D arrangement of atoms in space • Useful for visulising shape of molecule	• Atoms aren't solid sphere • Sticks represent bonds but there's no physical bond but electrostatic force of attraction • Atoms are placed far apart from each other but in reality the gaps between atoms are much smaller • X indicate movement of electrons

2D diagrams



Advantages	Disadvantages
• Displayed formulae are 2D representations and are basically simpler versions of the ball and stick model • Adequately indicate what atoms are in a molecule and how they are connected	• X illustrate the relative sizes of the atoms and bonds • X give you an idea of the shape of a molecule and what it looks like in 3D space Atoms are placed far apart from each other but in reality the gaps between atoms are much smaller

3D diagrams



Advantages	Disadvantages
• 3D drawings and models depict the arrangement in space of the ions • Show the repeating pattern in giant lattice structures	• Only illustrate the outermost layer of the compound • Difficult and time consuming to draw

2.1.3 Ionic compounds

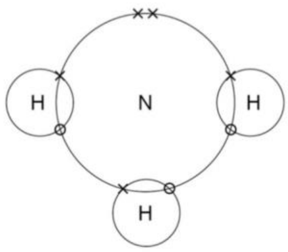
(See 2.1.2 Ionic bonding)

2.1.4 Covalent bonding

Covalent bonding

- Sharing of pair of electrons between non-metal atoms
- Electrostatic force of attraction between +ve nucleus & pair of -ve electrons
- Occurs in covalent compound
- Produce simple molecular compounds or giant covalent structure

For ammonia (NH_3)



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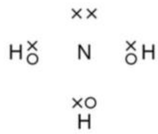

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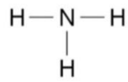

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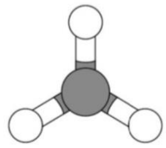
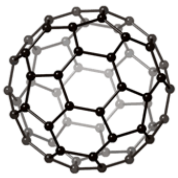
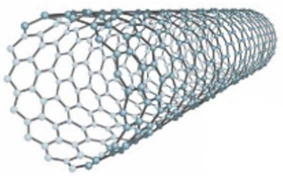


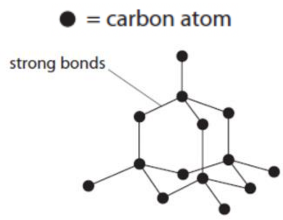
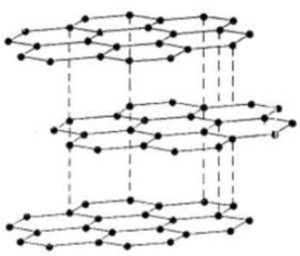
Simple molecular compounds

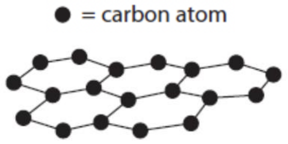
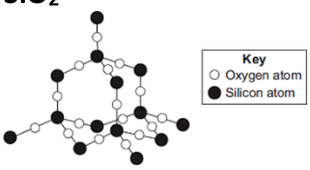
Fullerenes 	• Molecules of carbon atoms with hollow shapes • Hexagonal rings of carbon atoms but may also contain rings with 5 or 7 carbon atoms • 1st fullerene - Buckminsterfullerene (C_{60}) - has spherical shape	**Properties** • **Low melting point** • **X conduct electricity** • **Soft, brittle & lubricant** - shape like ball - roll **Uses** • Drug delivery • Lubricants
Carbon nanotubes 	• Long cylindrical fullerenes	**Properties** • **Strong** - high length to diameter ratios • **Conduct electricity** **Uses** • **Reinforce composite materials** eg tennis rackets - high tensile strength

Properties

Properties	Reasons
Low melting & boiling point	Weak intermolecular forces between molecules - easy to break
X conduct electricity	X free electrons

Giant covalent structure

Diamond 	• Each carbon bond to 4 other carbons covalently - hard	**Properties** • **High melting point** • **X conduct electricity** • **Hard & strong** • **Insoluble in water** **Uses** • Cutting tools
Graphite 	• Each carbon bond to 3 other carbons covalently • Form layers of hexagonal rings which have no covalent bonds between layers	**Properties** • **High melting point** • **Conduct electricity** - 1 electron from each carbon atom is delocalised • **Soft, brittle & slippery** - weak (intermolecular) forces between layers - easy to break - layers can slide over each other **Uses**

		• Electrodes, pencils, lubricant
Graphene 	• Single layer of graphite	**Properties** • **High melting point** • **Conduct electricity** • **Strong** - atoms within layers are tightly bonded covalently - lots of energy to break **Use** • In electronics, composites
Silicon dioxide (silica) SiO_2 	• Each silicon bond to 4 O_2 covalently • Each O_2 bond to 2 silicon covalently	**Properties** • **High melting & boiling point** • **X conduct electricity** • **Hard**

2.1.5 Metallic bonding

Metallic bonding

- Bonding of metal atoms to form solid
- Strong electrostatic attraction between closely packed +ve metal ions & sea of delocalised electrons
- Produce giant metallic structure
- Arranged in regular pattern

Properties

Properties	Reasons
High melting & boiling pt	(See above for reasons)
Conduct electricity & thermal energy	
Bend (ductile) & change shape (malleable)	

Alloys

- Mixture of 2 or more different types of metals
- **Not malleable/ductile, hard** - different size of atoms disrupt structure - harder to slide - harder than pure metal

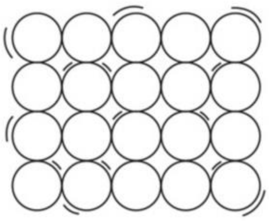
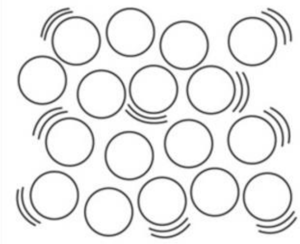
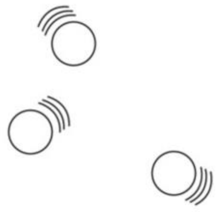
Smart alloys - return to original shape

2.2 How bonding and structure are related to the properties of substances

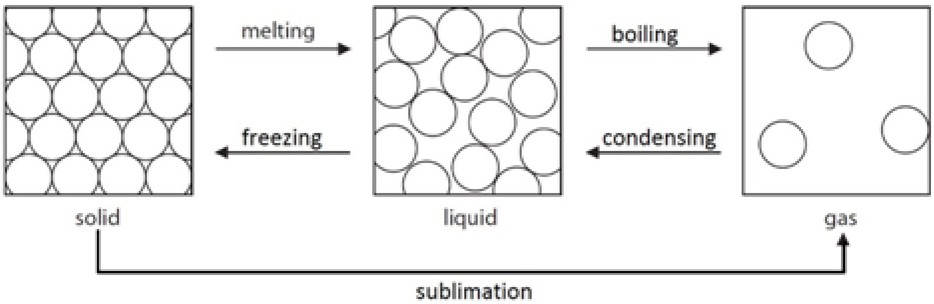
2.2.1 The three states of matter

Properties of Solids, Liquids and Gases

Solid	Liquid	Gas

		
• Close together in regular pattern • Strong intermolecular force of attraction • Vibrate at fixed position • Fixed shape & volume	• Close together in random pattern • Further apart than solid • Weaker intermolecular force of attraction • Slide past each other • Can't be compressed coz large intermolecular forces when molecules moved closer	• Far apart in random pattern • Weaker intermolecular force of attraction • Move quickly in all directions • Can flow or compress

State Changes



States of matter can be represented using a model called particle theory.
How are particles represented in this model? (1)

- Small solid spheres

Explain the limitations of particle theory (2)

- Doesn't show forces between particles
- Particles are not solid spheres

Particle theory can be used to explain changes of state.
Using particle theory, explain how a substance changes from a liquid to a gas when it is heated. (3)

- When a liquid is heated, particles gain KE & move faster
- Weakens bonds holding liquid tgt
- At certain temp, particles have sufficient energy to break bonds
- Liquid becomes gas

2.2.2 State symbols

Solid (s), Liquid (l), Gas (g), Aqueous solution (aq)

2.2.3 Properties of ionic compounds

(See 2.1.2 Ionic bonding)

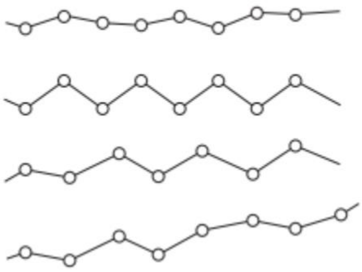
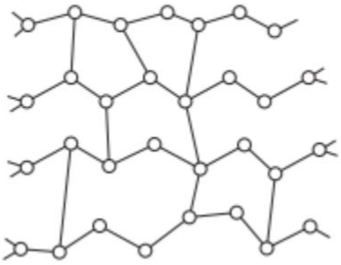
2.2.4 Properties of small molecules

(See 2.1.4 Covalent bonding)

2.2.5 Polymers

- Long chain molecule made from joining many short molecules (monomers) together

- **Strong intermolecular force** - hard to break - solid at room temp
- Different polymers, different properties, different uses

Thermosoftening polymer	Thermosetting polymer
	
• Contain long polymer chains • Chains are not joined tgt (but are tangled up with each other) • Low melting point - soften and then melt when heated	• Contain long polymer chains • Chains are joined by covalent bonds • High melting point - do not soften or melt when heated

2.2.6 Giant covalent structures

(See 2.1.4 Covalent bonding)

2.2.7 Properties of metals and alloys

(See 2.1.5 Metallic bonding)

2.2.8 Metals as conductors

(See 2.1.5 Metallic bonding)

2.3 Structure and bonding of carbon

2.3.1 Diamond

2.3.2 Graphite

2.3.3 Graphene and fullerenes

(See 2.1.4 Covalent bonding)

2.4 Bulk and surface properties of matter including nanoparticles (chemistry only)

2.4.1 Sizes of particles and their properties

Nanoparticles

- 1-100nm in size, a few hundred atoms thick
- High SA:vol ratio
- Smaller than **fine particles ($PM_{2.5}$)** – diameters between 100-2500nm (1×10^{-7}-2.5×10^{-6}m)
- **Coarse particles (PM_{10})** – diameters between 1×10^{-5}-2.5×10^{-6}m – often referred to as **dust**

Why good?

- Stronger, harder, high SA:V ratio, very small - fit in small gaps

2.4.2 Uses of nanoparticles

Uses

- Catalyst for fuel - large SA:V ratio
- Drug delivery - tiny, absorb easily by body
- Sun cream - better skin coverage, more effective protection from UV rays

Problems

- Potential cell damage in body
- Harmful effects on environment

Suggest why using nanoparticles is good for environment? (2)

- Tennis ball last longer (coz keep it hard)
- Less tennis ball needed to make
- Less material/energy used, pollution caused, waste

Suggest and explain why use of nanosized catalyst particles reduce cost of catalytic converter. (3)

- 1-100nm in size
- Large SA
- Less catalyst needed