CHEMICAL BONDING AND STRUCTURE

5.1

ionic bonding : transfer of electrons from a metal atom to a non-metal atom to form positive and negative charged ions with a noble gas electronic structure

metal atoms lose electrons – positive ion (cation)

non-metal atoms gain electrons – negative ion (anion)

ionic bonds : electrostatic forces of attraction between the positive and negative charged ions

eg 1 : sodium chloride

sodium (metal) : 2.8.1

chlorine : 2.8.7

sodium atom loses 1 electron to form a sodium ion in order to achieve a noble gas electronic configuration [2.8]

chlorine atom gains 1 electron to form a chloride ion in order to achieve a noble gas electronic configuration [2.8.8]

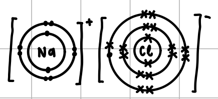
there is a transfer of electron from sodium atom to chlorine atom

ionic compound is called sodium chloride – consists of sodium ions + chloride ions

$Na\ (2.8.1) \rightarrow Na^{+} + e^{-}$

$Cl\ (2.8.7) + e^{-} \rightarrow Cl^{-}\ (2.8.8)$

diagram :



eg 2 : magnesium oxide

magnesium : 2.8.2

oxygen : 2.6

magnesium atom will lose 2 electrons to form a magnesium ion in order to achieve a noble gas electronic configuration [2.8]

oxygen atom will gain 2 electrons to form an oxygen ion in order to achieve a noble gas electronic configuration [2.8]

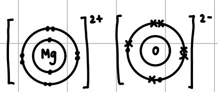
transfer of electrons from magnesium atom to oxygen atom

ionic compound is called magnesium oxide – consists of magnesium ions and oxygen ions

$Mg\ (2.8.2) \rightarrow Mg^{2+} + 2e^{-}$

$O\ (2.6) + 2e^{-} \rightarrow O^{2-}$

magnesium oxide :



eg. 3 : calcium chloride

calcium : 2.8.8.2

chlorine : 2.8.7

a calcium atom will lose 2 electrons to form a calcium ion in order to achieve a noble gas electronic configuration 2.8.8

a chlorine atom will gain 1 electron to form a chloride ion in order to achieve a noble gas electronic configuration 2.8.8

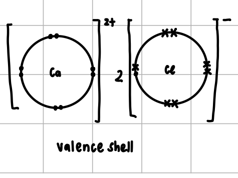
there is a transfer of electrons from 1 calcium atom to 2 chlorine atoms

the ionic compound is called calcium chloride and consists of calcium ions and chloride ions

formation of calcium chloride, $CaCl_2$

$Ca\ (2.8.8.2) \rightarrow Ca^{2+}\ (2.8.8) + 2e^{-}$

$2Cl\ (2.8.7) + 2e^{-} \rightarrow 2Cl^{-}\ (2.8.8)$



eg 4: potassium oxide

potassium: 2.8.8.1

oxygen: 2.6

a potassium atom will lose 1 electron to form a potassium ion in order to achieve a stable noble gas configuration

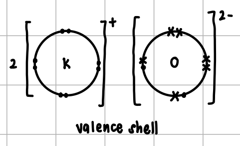
an oxygen atom will gain 2 electrons to form an oxygen ion in order to achieve a stable noble gas configuration

there is a transfer of electrons from 2 potassium atoms to 1 oxygen atom

ionic compound is called potassium oxide and consists of potassium ions and oxide ions

formation: $2K(2.8.8.1) \rightarrow 2K^{+} + 2e^{-}$

$O(2.6) + 2e^{-} \rightarrow O^{2-}$



NOTE:

ionic compounds can be formed from non-metals too

eg. ammonium chloride

5.2

covalent substances are formed by covalent bonding

covalent bonding : sharing of electrons between two non-metal atoms to achieve a noble gas electronic configuration

covalent bond : the electrostatic attraction between the nuclei and the shared pair of electron between the two atoms

number of covalent bonds formed between 2 atoms depend on the number of valence electrons being shared

if two atoms share :

one pair of electrons, single bond is formed

Cl-Cl

two pairs of electrons, a double bond is formed

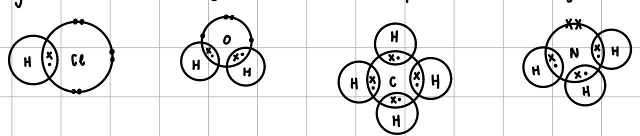
O=O

three pairs of electrons, a triple bond is formed

N≡N

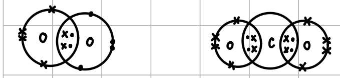
single covalent bonds are formed between two non-metals by the sharing of one valence electron by each atom

hydrogen chloride HCl: water H_2O: methane CH_4: ammonia NH_3:



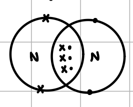
double covalent bonds are formed between two non-metal atoms by sharing of two valence electrons by each atom

oxygen O_2: carbon dioxide CO_2:



triple covalent bonds are formed between two non-metal atoms by sharing three valence electrons by each atom

nitrogen N_2:



NOTE:

carbon monoxide is a special case where the oxygen atom donates a pair of electrons to the carbon atom to achieve a noble gas configuration. This is called dative bonding where the shared pair of electrons is contributed by one atom. In carbon monoxide, the carbon atom only contributes 2 electrons to share with two electrons from oxygen atom. Another 2 electrons are contributed by the oxygen atom alone. This results to the formation of a triple bond which is made up of one double bond and a dative bond.

5.3 [ionic]

structure & bonding

ionic compounds form giant ionic structures. They are arranged in a giant lattice (orderly arrangement) or crystal lattice

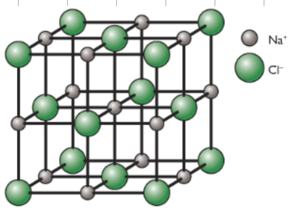
ionic compounds consists of ions held by strong electrostatic forces of attraction between positive and negatively charged ions

lattice structure of sodium chloride

the ions are arranged in such a way that each Na^+ ion is surrounded by six Cl^- ions. Each Cl^- ion is surrounded by six Na^+ ions

ratio of $Na^+ : Cl^- \rightarrow 1:1$

formula : $NaCl$



physical properties of ionic compounds

ionic compounds have high melting and boiling points and are non-volatile substances. these ions are held together by strong electrostatic attraction between the oppositely charged ions so a lot of energy is required to break down the lattice structure

ionic compounds conduct electricity if in the molten state or dissolved in water (aqueous state). In the molten or aqueous state, the ions are mobile so electrical conduction is possible

In the solid state, the ions are held in fixed positions in the lattice structure so ionic compounds cannot conduct electricity as there are no free-moving charge carriers

Ionic compounds dissolve in inorganic solvents (water) but not in organic solvents (ethanol, petrol, turpentine)

5.4 [covalent]

structure & bonding

covalent substances have simple molecular structures or giant molecular structures

eg. of simple molecular structures: water, methane & carbon dioxide

eg. of giant molecular structures: diamond, graphite

simple molecular structure

- volatile as a result of their low melting point and boiling point due to the weak intermolecular forces between simple molecules, very little heat energy is required to overcome the intermolecular forces hence these simple molecular substances have low boiling and melting points too
- most simple molecular substances do not conduct electricity whether in solid, liquid or gaseous state. This is because they do not have free-moving ions or electrons to conduct electricity
- most simple molecular compounds are insoluble in water and soluble in organic solvents. However, alcohol and sugar are exceptions which are soluble in water. Some simple molecules (eg. water, chlorine & hydrogen chloride) dissociate water

NOTE:
exceptions such as hydrogen chloride & ammonia which can dissociate in water to form ions, hence, able to conduct electricity due to the mobile ions formed

common simple molecular elements:

- bromine $[Br_2]$
- sulfur $[S]$
- chlorine $[Cl_2]$
- Nitrogen $[N_2]$
- Iodine $[I_2]$
- Oxygen $[O_2]$
- Carbon $[C]$
- ozone $[O_3]$

some common simple molecular substances:

- ammonia $[NH_3]$
- methane $[CH_4]$
- hydrogen peroxide $[H_2O_2]$
- water $[H_2O]$

macromolecules or giant molecular substances:

macromolecules are extremely large molecules

they contain billions of atoms per molecule

eg of macro molecules:

diamond, graphite, silicon, silicon dioxide (silica) diamond:

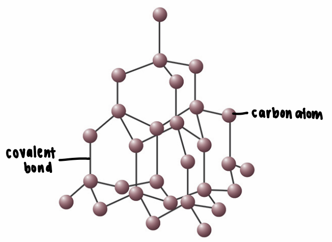
bonding

consists of only carbon atoms

each carbon atom uses all its four valence electrons to form four strong covalent bonds with four other carbon atoms in a tetrahedral arrangement

all the carbon atoms are bonded together by strong covalent bonds in a three-dimmensional lattice

giant molecular structure of diamond



properties

one of hardest substances known to mankind

carbon atoms are not able to slide over each other because all the atoms are bonded together by strong covalent bonds between carbon atoms in a giant molecular structure which require large amount of energy to break

very high melting point & boiling point :

a lot of energy is needed to break the many strong covalent bonds between carbon atoms

cannot conduct electricity :

each carbon atom uses all its valence electrons for bonding. Hence, there are no free-moving electrons to carry the electric current through the structure

NOTE:

"carbon uses all its electrons for bonding and thus, unable to conduct electricity" X two innermost electrons of carbon are not involved in bonding

use of diammond :

- gemstones in jewellery

- synthetic diammonds produced under extreme pressures and temperatures are used as tips of drills and other cutting tools

- used for drilling, polishing very hard surfaces

graphite :

bonding

only consists of carbon

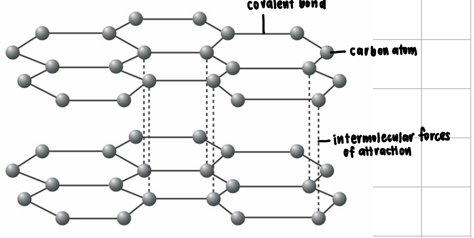
allotrope of carbon [allotrope : different forms of the same element, that is different arrangements of atoms]

consists of hexagonal layers of carbon atoms. the layer of carbon atoms lie one on top of the other and are held by weak intermolecular forces

in each layer,

each carbon atom uses only three out of its four valence electrons to form three covalent bonds to three other carbon atoms in a hexagonal arrangement

this forms hexagonal rings of six carbon atoms that join together to form two dimmensional flat layers



properties

high melting & boiling point

a lot of energy is needed to overcome the numerous strong covalent bonds between carbon atoms

extremely soft substance

hexagonal layers of carbon atoms are able to slide over each other because the weak intermolecular forces of attraction between the layers of carbon can be easily overcome with little energy

conducts electricity

each carbon atom uses only three valence electrons for bonding. Hence, there are free-moving (delocalised) electrons contributed by each carbon atom which can carry the electric current between the layers in graphite

uses:

- lubricate machine parts

- made into pencil lead by baking with clay

- used to make inert electrodes for electrolysis & brushes for electric motors

silicon

bonding

silicon has a giant molecular structure which is similar to diamond

each silicon atom uses all four valence electrons to form four covalent bonds with four other silicon atoms

each silicon atom is bonded together by strong covalent bonds in a three-dimmensional lattice properties

hard but not as hard as diamond

high melting & boiling point

does not conduct electricity but can be a semiconductor when there are impurities

silicon dioxide

bonding

silicon dioxide has a giant molecular structure which is similar to diammond

each silicon atom is bonded to four other oxygen atoms in a tetrahedral arrangement

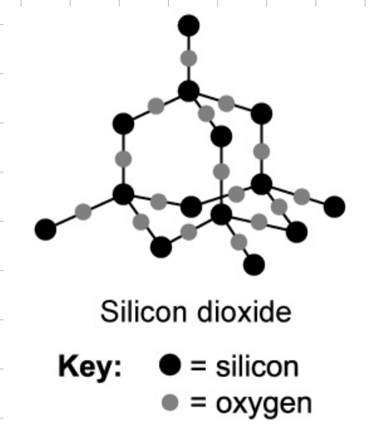
each silicon atom forms 4 covalent bond to 4 oxygen atoms

properties

hard but not as hard as diamond

high melting & boiling point

poor conductor of electricity



5.5

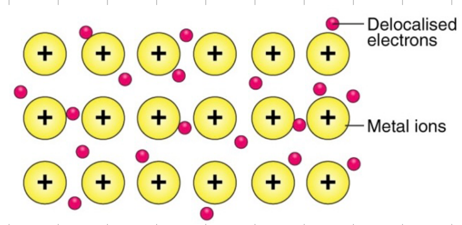
structure & bonding of metals

metal atoms have a tendency to lose their valence electrons to achieve the noble gas configuration

metal atoms lose their valence electrons to become positive ions

delocalised electrons: valence electrons no longer belong to any metal atoms. They can move freely among the metal ions.

metallic bonds: the electrostatic forces of attraction between the positive charged metal ions and the 'sea of mobile electrons'



physical properties

metals are usually solids at room temperature [except for mercury which is a liquid at room temp]

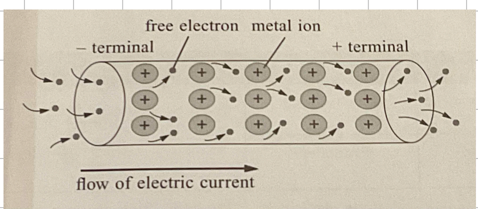
-most metals have high melting and boiling point, therefore, they are solids at room temp.

this is because a lot of energy is needed to break the strong electrostatic forces of attraction between the positive ions and the 'sea of delocalised electrons'

NOTE: transition metals like iron and tungsten have high melting points but other metals like those in Group 1 and mercury have generally lower melting and boiling points

metals are good conductors of heat & electricity

metals have free-moving electrons to act as mobile charge carriers to carry electrical current and heat energy



properties of metals

high density: atoms in a metal are usually packed as closely as possible [eg. iron & copper]

malleable, ductile: regular arrangement of atoms allows them to slide over one another if an external force is applied [eg. drink cans, aluminium foil, copper wires]

conduct electricity: presence of 'sea' of delocalised electrons surrounding the lattice of positive 'metal ions' [eg. copper wires, electrical goods]
(to distinguish metals from non-metals)

high melting and boiling point: strong metallic bonding and close packing of 'metallic ions' [eg. tungsten filament in light bulbs]
(except mercury that is a liquid at room temp.)

Alloys:

alloy: a mixture of metals and one or more elements. [eg. steel contains mainly iron together with carbon and small amounts of other elements]

alloys are generally:

- harder & stronger
- better in appearance
- lower in melting points
- more resistant to corrosion

	brass: copper + zinc	bronze: copper+tin	solder: tin+lead	stainless steel: iron+chromium+nickel+carbon	duralumin: aluminium+copper
uses:	electric plug	propellers	joining electrical connections	cutlery	aircraft body
remark:	harder, stronger than pure metals	harder, stronger than pure metals	lower melting point than pure tin or lead	strong, durable; resistant to rusting (Cr_2O_3 protective layer)	strong, hard & lightweight

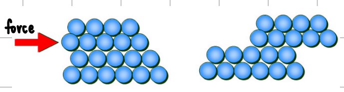
	pewter: lead+tin+copper+antimony
uses:	souvenirs
remark:	harder than pure tin & has more beautiful appearance

properties & uses of alloys

alloys are much stronger and harder than pure metals

reason: pure metals are malleable because the regularly arranged layers of atoms can slide over each other easily

this movement is known as slip

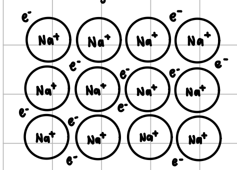


pure metals are soft because layers of "atoms" can slide over one another

in the alloy structure, the size of the atoms of the added element is different from that of the main metal. This will disrupt the regular arrangement of the metal atoms and prevent the slip because atoms of different sizes cannot slide over each other. Hence, alloys are harder

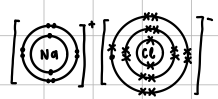
drawing:

metallic bonding:



ionic bonding

sodium chloride (NaCl)



① 9-12 circles, touching e/o is okay

② charge of cation reflected in drawing

③ no. of delocalised electrons = no. of cation × no. of e⁻ lost.

5.7

noble gases, located in group 18

properties

- low melting & boiling points
- insoluble in water
- colourless gases at room temperature
- odourless
- inert/unreactive → why?

noble gases have a fully filled valence shell of eight electrons

means that they do not lose, gain or share electrons with other elements

∴ unreactive, monatomic

uses:

helium: to fill weather balloons, advertisement balloons and airships

neon: make lights & advertisement signs

argon: fill tungsten light bulbs

xenon: used in vehicle headlamps