4 States of matter

Ideal Gas Equation

The ideal gas equation applies to all gases and mixtures of gases. If a mixture of gases is used the value n will be the total moles of all gases in the mixture.

PV = nRT

Unit of Pressure (P):Pa
Unit of Volume (V): $\mathbf{m^3}$
Unit of Temp (T): K
n= moles
R = 8.31 $JK^{-1}mol^{-1}$

The biggest problems students have with this equation is choosing and converting to the correct units, so pay close attention to the units.

An ideal gas has the following properties:

1. An ideal gas is considered to be a "point mass". A point mass is a particle so small that its mass is very nearly zero. This means an ideal **gas particle has almost no volume**.

2. There are **no attractive** or repulsive forces involved during collisions. Also, the kinetic energy of the gas molecules remains constant since the intermolecular forces are lacking.

These assumptions do not actually hold true for many gases. They work best for the Noble gases. Heavier gases and ones with significant intermolecular forces will deviate from ideal gas behaviour

There are also limitations of ideality at very high pressures and very low temperatures. Under these conditions the particles will be closer together and the intermolecular forces between the closer particles will cause a deviation from ideal behaviour

Example 1: What is the mass of Cl_2 gas that has a pressure of 100kPa, temperature 20°C , volume 500cm³. (R = 8.31)

moles = PV/RT
= 100 000 x 0.0005 / (8.31 x 293)
= 0.0205 mol

100 kPa = 100 000 Pa
20°C = 20+273= 293K
500 cm³ = 0.0005 m³

Mass = moles x Mr
= 0.0205 x (35.5 x2)
= 1.46 g

Converting temperature

°C → K add 273

Example 2: 0.150g of a volatile liquid was injected into a sealed gas syringe. The gas syringe was placed in an oven at 70°C at a pressure of 100kPa and a volume of 80cm³ was measured. What is the Mr of the volatile liquid ? (R = 8.31)

moles = PV/RT
= 100 000 x 0.00008 / (8.31 x 343)
= 0.00281 mol

100 kPa = 100 000 Pa
80 cm³ = 0.00008 m³

Mr = mass/moles
= 0.15 / 0.00281
= 53.4 g mol^{-1}

Changing the Conditions of a gas

Questions may involve the same amount of gas under different conditions.

Example 3
40 cm^3 of oxygen and 60 cm^3 of carbon dioxide, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.50 dm^3. What is the pressure of the gas mixture in the flask at 298 K?

There are two approaches to solving this
1. Work out moles of gas using ideal gas equation then put back into ideal gas equation with new conditions
2. Or combine the equation n= PV/RT as on right

Can do this as moles of gas do not change

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

As Temperature is the same can make the above equation $P_1V_1 = P_2V_2$

$P_2 = P_1V_1 / V_2$

$= 100000 \times 1\times 10^{-4} / 5\times10^{-4}$

$= 20\ 000$Pa

Reacting Volumes of Gas

Equal volumes of any gases measured under the same conditions of temperature and pressure contain equal numbers of molecules (or atoms if the gas in monatomic)

1 mole of any gas at room pressure (1atm) and room temperature 25^oC will have the volume of 24dm^3

Volumes of gases reacting in a balanced equation can be calculated by simple ratio

Example 4 If one burnt 500 cm^3 of methane at 1atm and 300K what volume of Oxygen would be needed and what volume of CO_2 would be given off under the same conditions?

$CH_4(g)$ +	**2** $O_2(g)$ →	$CO_2(g)$ + $2\ H_2O(l)$
1 mole	**2** mole	1 mole
500cm^3	1dm^3	500cm^3

Simply multiply gas volume x2

Example 5 An important reaction which occurs in the catalytic converter of a car is
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$
In this reaction, when 500 cm^3 of CO reacts with 500 cm^3 of NO at 650 °C and at 1 atm.
Calculate the **total** volume of gases produced at the same temperature and pressure ?

2CO(g) +	2NO(g) →	$2CO_2(g)$ +	$N_2(g)$
500cm^3	500cm^3	**500cm^3**	**250cm^3**

total volume of gases produced = 750cm^3

Using a gas syringe

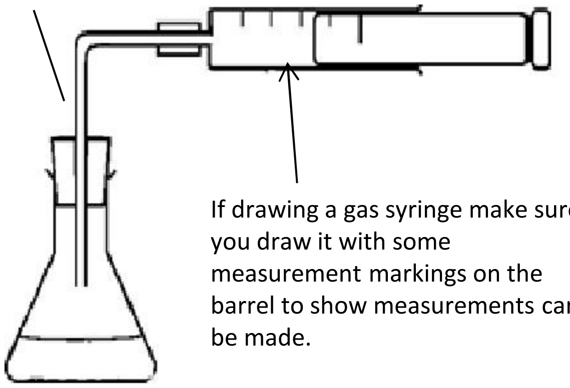
Gas syringes can be used for a variety of experiments where the volume of a gas is measured, possibly to work out moles of gas or to follow reaction rates.

The volume of a gas depends on pressure and temperature so when recording volume it is important to note down the temperature and pressure of the room.

Moles of gas can be calculated from gas volume (and temperature and pressure) using ideal gas equation $PV = nRT$

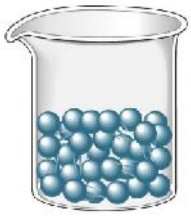
Potential errors in using a gas syringe
•gas escapes before bung inserted
•syringe sticks
• some gases like carbon dioxide or sulphur dioxide are soluble in water so the true amount of gas is not measured.

Make sure you don't leave gaps in your diagram where gas could escape



If drawing a gas syringe make sure you draw it with some measurement markings on the barrel to show measurements can be made.

The liquid state



Liquid particles are randomly arranged
Liquids particles are closely spaced but still in constant motion, and therefore are constantly colliding

Melting. If a solid is heated by supplying energy through heating, the energy will cause larger vibrations. Eventually the particles will have enough energy to break away from the solid arrangement to become a liquid.

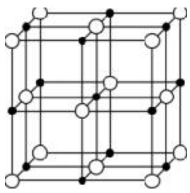
Evaporation: In a liquid some of the particles near the surface of the liquid may gain enough energy to leave the liquid as gas particles. This is **vaporisation.**
If the liquid is in a sealed container the gas particles produced through vaporisation will exert a pressure on the container. This is called the **vapour pressure.** If the liquid/gas is allowed to reach an equilibrium then the pressure exerted by the vapour can be called the saturated vapour pressure

The solid state: lattice structures

Types of crystal structure: ionic, metallic, molecular and giant covalent (macromolecular).

You should be able to draw the following diagrams or describe the structure in words to show the four different types of crystal. You should also be able to explain the properties of these solids. The tables in the bonding revision guide explain these properties.

Ionic: sodium chloride



Giant Ionic lattice showing alternate Na^+ and Cl^- ions

The ions in an ionic solid are arranged in a regular 3D pattern called a giant ionic lattice

The sticks in this diagram are there to help show the arrangements of the ions. They do not represent the ionic bonds.

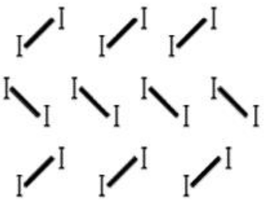
Ionic bonding is between ions and all their surrounding oppositely charged ions. Each sodium ion in this structure is surrounded and equally attracted by six chloride ions. The ionic bond is the attraction between all these ions

Typical Physical properties of Ionic Compounds

•High melting points - There are strong electrostatic attractive forces between the oppositely charged ions in the lattice
•Non conductor of electricity when solid- The ions are held together tightly in the lattice and can not move so no charge is conducted
•Good conductor of electricity when in solution or molten – The ions are free to move when in solution and molten. Charge can be carried

- They are **usually** soluble in aqueous solvents.

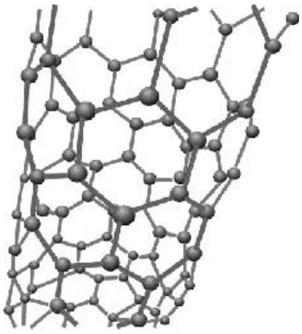
Molecular: Iodine



The crystals contain a regular arrangement of I_2 molecules held together by weak induced dipole–dipole interactions intermolecular forces

There are covalent bonds between the Iodine atoms in the I_2 molecule

Molecular : Carbon Fullerenes Nanotubes and C_{60}

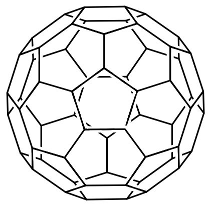


Nanotubes and C_{60} are classed molecular as they have fixed formula.

Nanotubes have very high tensile strength because of the strong structure of many strong covalent bonds

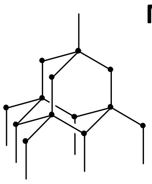
Nanotubes can conduct electricity well along the tube because one electron per carbon is free and delocalised, so electrons can move easily along the tube.

There are delocalized electrons in C_{60}



Giant molecular

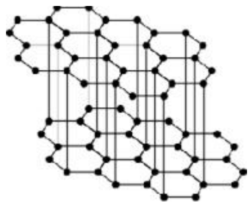
Macromolecular: diamond



Tetrahedral arrangement of carbon atoms. 4 covalent bonds per atom

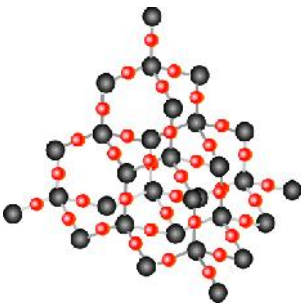
Diamond cannot conduct electricity because all 4 electrons per carbon atom are involved in covalent bonds. They are localised and cannot move

Macromolecular: Graphite



Planar arrangement of carbon atoms in layers. 3 covalent bonds per atom in each layer. 4th outer electron per atom is delocalised. Delocalised electrons between layers.

Graphite can conduct electricity well between layers because one electron per carbon is free and delocalised, so electrons can move easily along layers.
It does not conduct electricity between layers because the energy gap between layers is too large for easy electron transfer.



Macromolecular: silicon dioxide

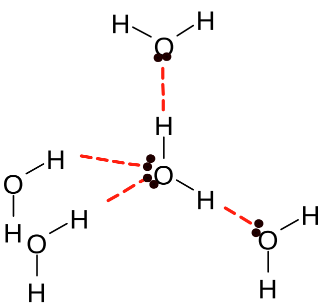
Tetrahedral arrangement. Each carbon atom forms 4 covalent bonds to an oxygen. Each oxygen forms two covalent bonds to carbons

All these macromolecular structures have very high melting points because of strong covalent forces in the giant structure. It takes a lot of energy to break the **many strong** covalent bonds

Graphene

Graphene is a new substance that is a one layer of graphite .i.e. 3 covalent bonds per atom and the 4th outer electron per atom is delocalised.
These have very high tensile strength because of the strong structure of many strong covalent bonds
Graphene can conduct electricity well along the structure because one electron per carbon is free and delocalised, so electrons can move easily along the structure.

Molecular: Ice



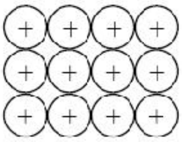
This is a difficult diagram to draw.

The main point to show is a central water molecule with two ordinary covalent bonds and two hydrogen bonds in a tetrahedral arrangement

The molecules are held further apart than in liquid water and this explains the lower density of ice

Metallic: magnesium or copper

Use this diagram for any metal

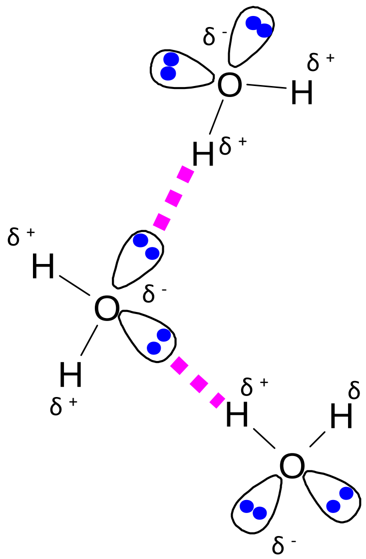


Giant metallic lattice showing close packing magnesium **ions**

Metals can conduct electricity well because the delocalised electrons can move through the structure

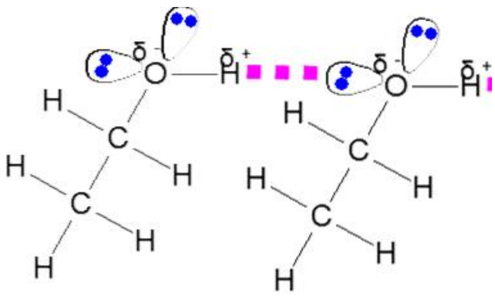
Metals are malleable because the positive ions in the lattice are all identical. So the planes of ions can slide easily over one another. The attractive forces in the lattice are the same whichever ions are adjacent

Hydrogen bonding



Water can form two hydrogen bonds per molecule, because the electronegative oxygen atom has two lone pairs of electrons on it.
It can therefore form stronger hydrogen bonding and needs more energy to break the bonds, leading to a higher boiling point.

Alcohols form hydrogen bonds. This means alcohols have higher boiling points and relatively low volatility compared to alkanes with a similar number of electrons



The strength of hydrogen bonding can also lead to higher viscosity and surface tension in substances that have hydrogen bonding.
Propane-1,2,3-triol has 3 –OH groups per molecule and therefore can form multiple hydrogen bonds per molecule. It is a very viscous liquid.