THE GAS LAWS

1. **What are the different states of matter?**

   Matter comes in three states that are distinguished by the strength of the bonds holding the molecules of the matter together.

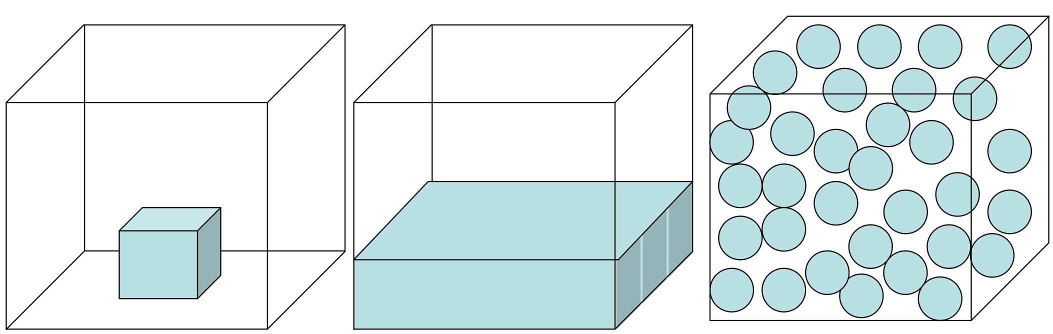
   The three states of matter are: solids, liquids and gases.

2. **Explain how the molecules are arranged in solids, liquids and gases.**

   Solids: Molecules are arranged in a regular formation called **lattice**. Each molecule in the lattice is in a continuous motion, oscillating about a mean position. Solids hold their shape and have fixed volume

   Liquids: the molecules have more vibrational energy. The molecules are held together by weak forces called **'Van der Waals'** forces. Liquids also have fixed volume like solids but they take shape of the container. The liquids have a free surface.

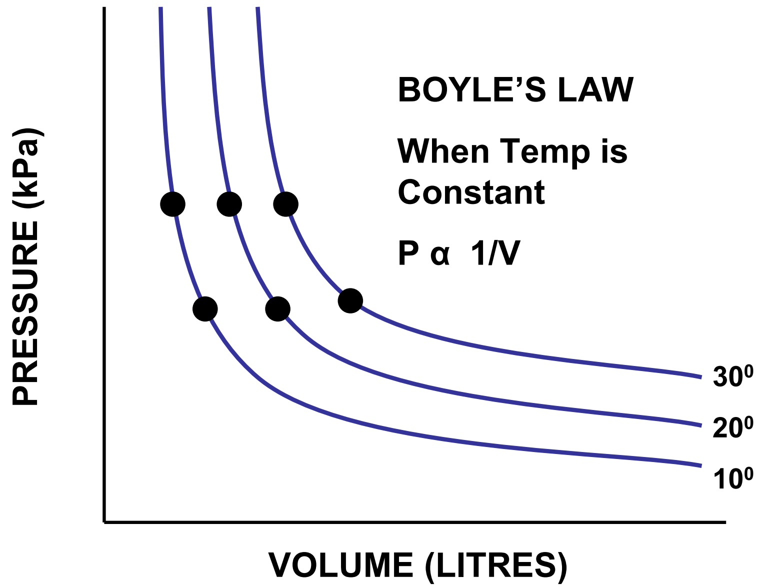
   Gases: the molecules are able to overcome the 'van der waals' forces and escape the surface of the liquid. Gases also take the shape of the container like the liquids and will fill the space it is contained in but they do not have a free surface.



Solids Liquids Gases

3. **State Boyle's law and explain how the law can be used to calculate the content of an oxygen cylinder.**

   Boyle's law sates that at constant temperature the volume of a given mass of gas varies inversely with the absolute pressure.



Calculating volume of gas available to use from a pressurised cylinder.

Cylinder volume = 10 Lit

Cylinder pressure when full =137bar or 13, 700 kPa

Atmospheric pressure = 100kPa

Absolute pressure in the cylinder = 13,800 kPa

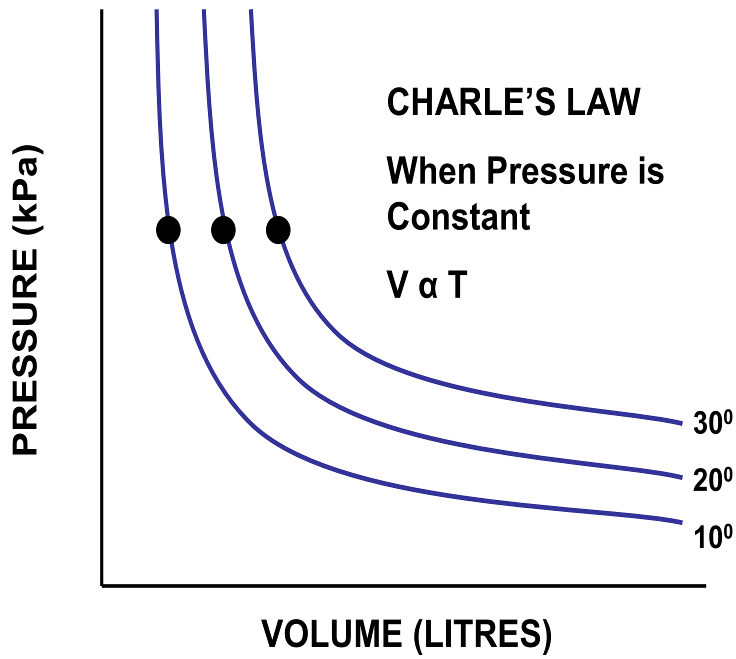
$$P_1 \times V_1 = P_2 \times V_2$$

$$V_2 = \frac{P_1 \times V_1}{P_2}$$

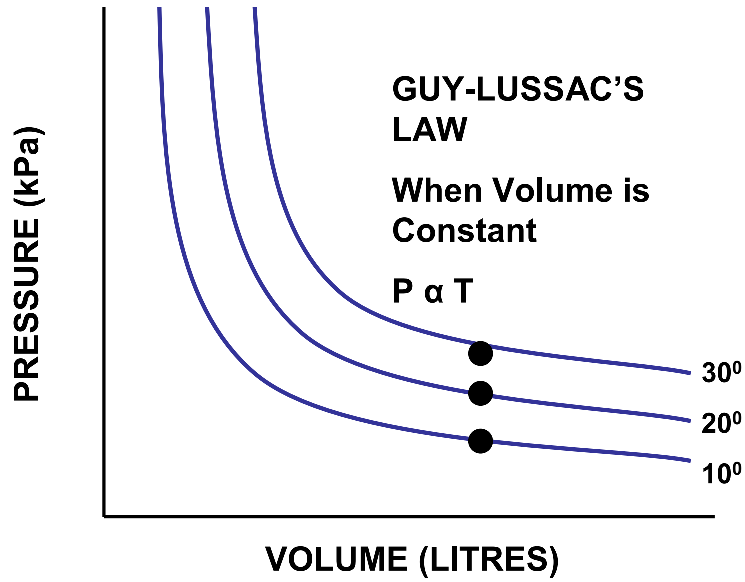
V_2 = 13,800 x 10/ 100 = 1380 Lits and since the volume of cylinder is 10 Lits the actual volume available for use is 1380 -10 Lits i.e 1370 Lits.

4. **State the second and third perfect gas laws.**

Charles' law states that at constant pressure the volume of a given mass of gas varies with the absolute temperature.



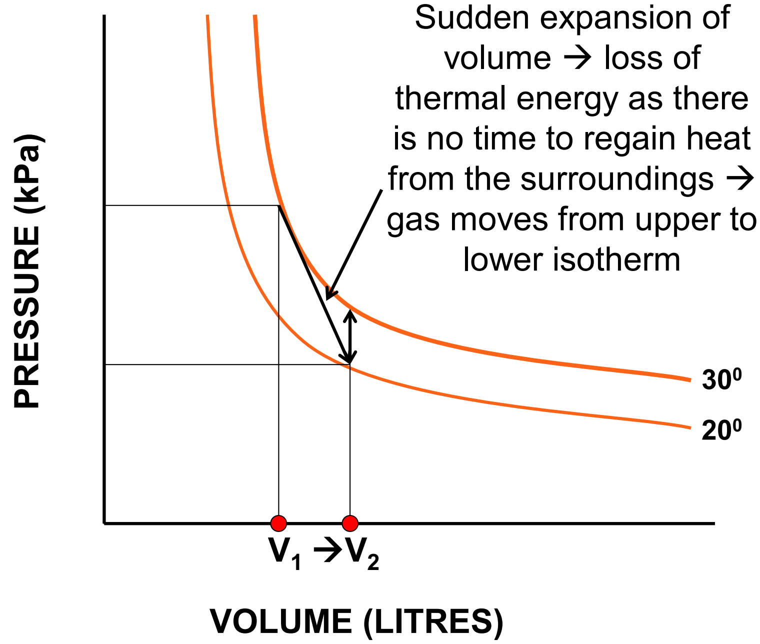
The third perfect gas or Guy-Lussac's law states that at constant volume the absolute pressure of a given mass of gas varies directly with the absolute temperature.



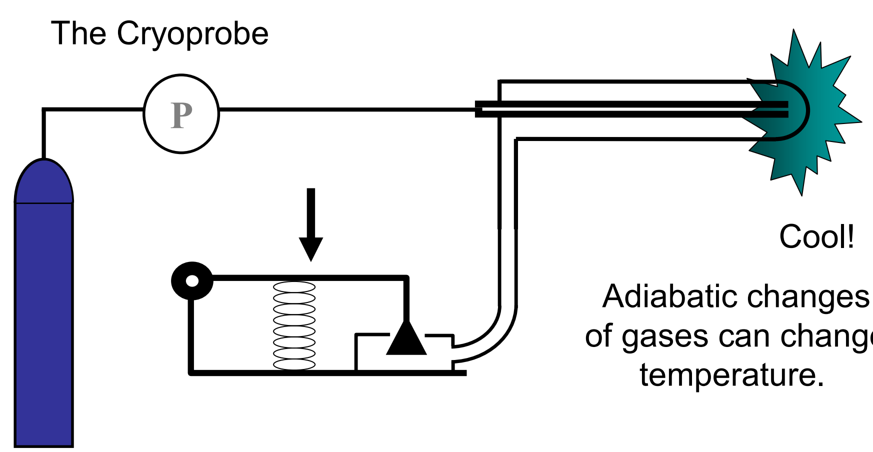
5. What is an adiabatic change? Explain with an example.

   Adiabatic process is a thermodynamic process in which the system undergoing the change, exchanges no heat with its surroundings.

   In an adiabatic process, compression always results in warming, and expansion always results in cooling.



If a compressed gas expands adiabatically, cooling occurs. This is the principle of a cryoprobe.



6. **State Dalton's law of partial pressures. Explain with an example.**

Dalton's law of partial pressure states that in a mixture of gases the pressure exerted by each gas is the same as that which it would exert if it alone occupied the container.

Entonox consists of 50% N_2O and 50% O_2, so each gas occupies half the cylinder volume. If the absolute pressure of the cylinder is 100kPa, then the partial pressure of N_2O or O_2 is 50% of 100kPa i.e 50kPa.

7. **What is the total pressure exerted by all the gases present in arterial blood?**

The sum of the partial pressures of the gases in arterial blood is about 713 mmHg. This is calculated by adding pO_2, pCO_2 and pN_2 as these are the only gases present in appreciable amounts.

This does not sum to 760 mmHg because of the water vapour present in alveolar gas. It does not make sense to speak of a pH_2O in water as this means talking of water dissolved in water! The saturated vapour pressure of water at 37°C is 47 mmHg and this is the water vapour pressure present in the alveoli.

8. **What does it mean to say 'the arterial pCO_2 is 40 mmHg'?**

This means that if a sample of this arterial blood was exposed to a gas phase with a pCO_2 of 40 mmHg, equilibrium for CO_2 would be present. The amount of CO_2 leaving the blood would equal the amount of CO_2 leaving the gas phase to enter the blood.

The actual concentration or amount of dissolved CO_2 present in the blood is not stated directly. Henry's law allows us to determine this amount because the amount dissolved is proportional to the partial pressure in the gas phase which is in equilibrium with the sample. If we know the constant of proportionality and the 'pCO_2 in the blood', then the amount dissolved can be determined.

For CO_2 in units of mmHg, the constant has a value of 0.03 mmol/l mmHg. For this example:

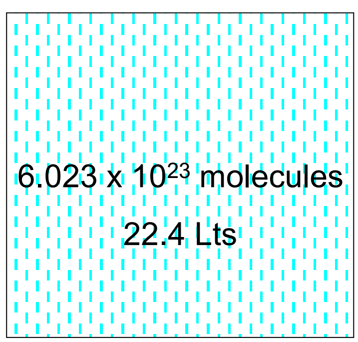
$$\text{Dissolved } CO_2 = 0.03 \times pCO_2 = 0.03 \times 40 = 1.2 \text{ mmols/l}$$

9. **What is Avogadro's hypothesis? How can this be used for calibration of vaporisers?**

Avogadro's hypothesis states that equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.

- **One mole of a gas** when allowed to expand until it reaches equilibrium with atmospheric pressure, will expand to fill a **volume of 22 litres**

- **Pressure** exerted by a given number of molecules of an ideal gas in a given volume and temperature is constant i.e **6.0224×10^{23} molecules in 22.4 litres** will exert a **pressure of 1 Atmosphere**



STP

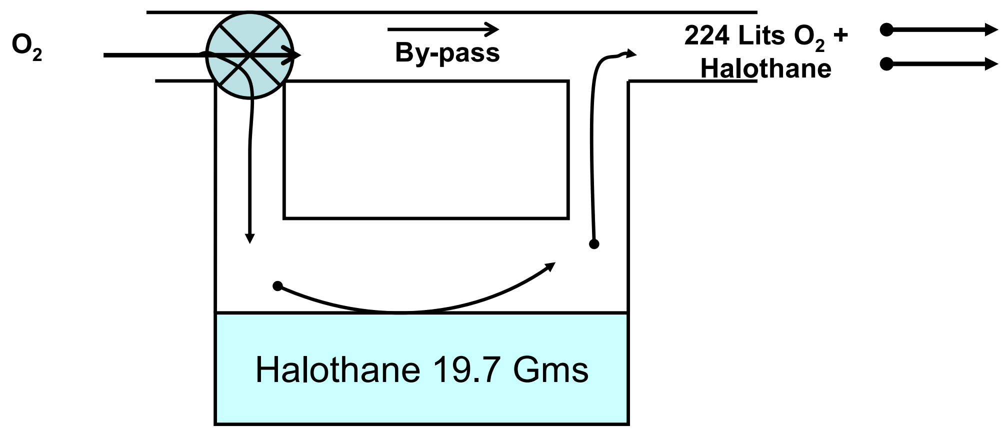
Imagine that in a vaporiser the oxygen vaporises all the 19.7 gms of Halothane to 224 lit of the mixture.

Mol wt of Halothane = 197

∴ 197 gms = 1mole and would occupy 22.4 Lits at STP (Avogadro's hypothesis).

19.7 gms (is 1/ 10th of 197) and therefore 0.1 moles (1/ 10th of 1 mole).

0.1 mole will therefore occupy, 0.1 x 22.4 lits i.e. 2.24 lits.



The halothane has been vaporised to 224 lit and therefore the concentration of halothane is 2.24/224 = 0.01 or 1/ 100 or 1%

10. What is a mole?

A mole is the quantity of a substance containing the same number of particles as there are atoms in 0.012kg or 12gms of carbon i.e 6.022 x 10^{23} (Avogadro's number)

1 mole of any gas at STP occupies 22.4Lits

11. **If a N_2O cylinder weighs 3.4Kg then what is the volume of N_2O in the cylinder.**

Mol wt of N_2O = 44 so 1 mole = 44gms = occupies 22.4 lits

3400gms (3.4 Kgs) will occupy, 22.4 x 3400/44 = 22.4 x 77.27 =1730 Lits

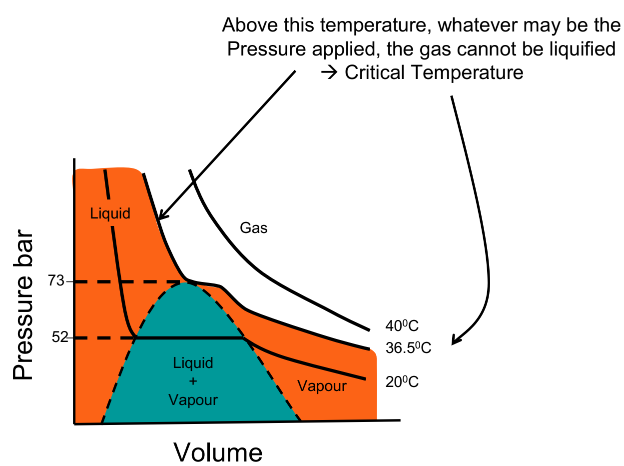
12. **Define the following terms**
    a) **Critical Temperature**
    b) **Critical Pressure**
    c) **Pseudo critical temperature.**

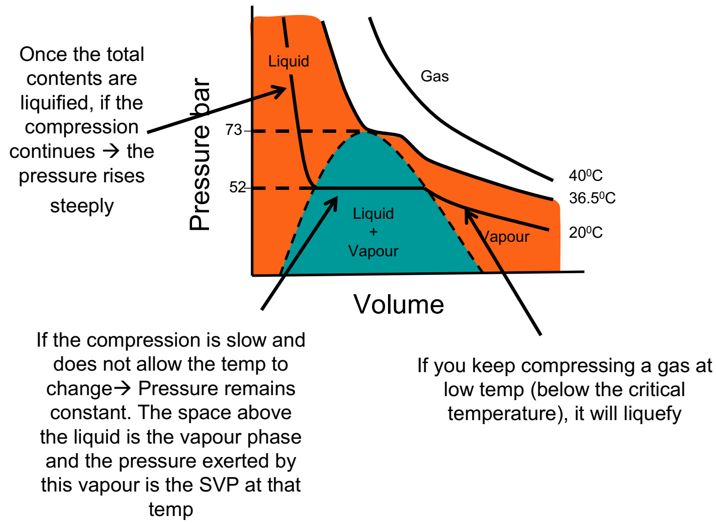
Critical temperature is the temperature above which a substance cannot be liquefied however much pressure is applied. e.g for N_2O Critical temperature is +36.5°C

Critical pressure is that which is required to liquefy a gas at its critical temperature

In a mixture of gases like Entonox, there is a specific critical temperature at which the mixture may separate out into its constituents; this temperature is called the **'pseudo critical temperature'**.

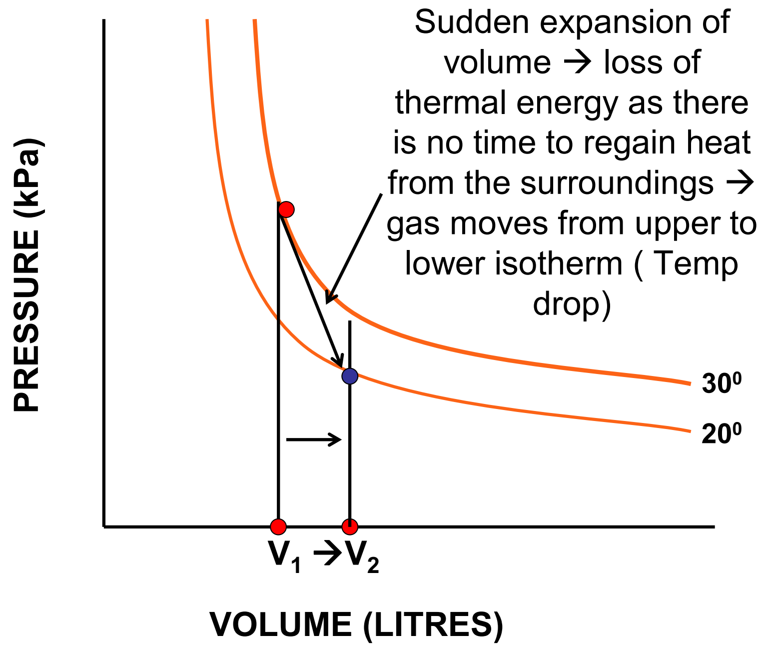
13. **Draw Isotherms for N_2O at 20°C, 36.5°C and 40°C.**





14. Explain what happens when a N_2O cylinder is suddenly opened.

Opening the N_2O cylinder suddenly has the same effect as what happens in the cryoprobe. When the valve is opened suddenly (and widely), the evaporation is rapid, the consumption of heat is correspondingly rapid. The temperature of the liquid N_2O, of the cylinder and of the air in the immediate neighbourhood falls sufficiently for the water vapour in the surrounding air to condense and even to freeze on the cylinder. As long as this happens outside the cylinder it is fine but if there is any water vapour in the cylinder itself, it will crystallize and block the exit valve; therefore the N_2O cylinders should always be opened slowly.



15. What is 'filling ratio' and what is it for N_2O in U.K?

Filling ratio is the mass of gas in a cylinder divided by the mass of water, which would fill the cylinder. Since the climate in UK is temperate the filling ratio for N_2O in UK is 0.75, whereas in the tropical climate the filling ratio is 0.67.