Lesson 11:1
(Please listen to the explanations, complete the graphs and then do 3 questions which will be discussed in the class)

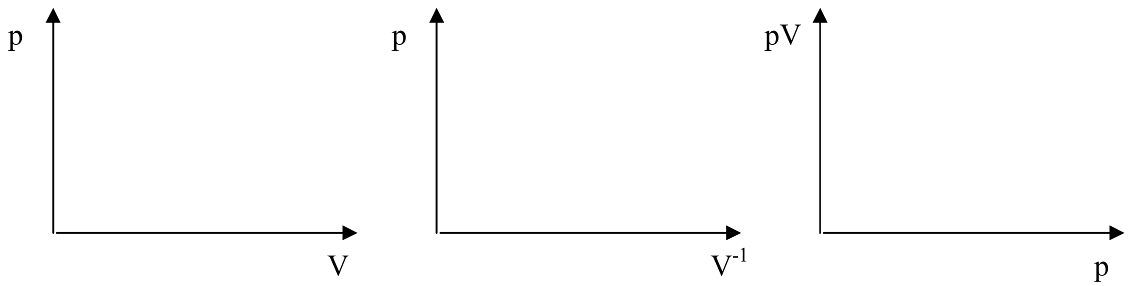
1. The gas laws

1.1. Boyle's law

For a fixed mass of gas at constant temperature, the pressure of the gas is **inversely** proportional to its volume

$p \propto \frac{1}{V}$ if T and m constant

$\therefore pV = \text{const}$

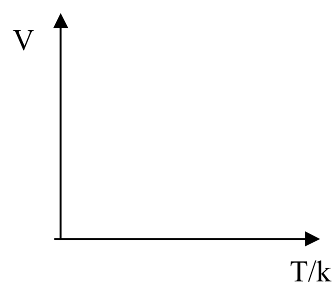


1.2. Charles's law

For a fixed mass of gas at constant pressure, the volume of the gas is **directly** proportional to its absolute temperature

$V \propto T$ if p and m constant

$\therefore \frac{V}{T} = \text{const}$ (T in kelvin)

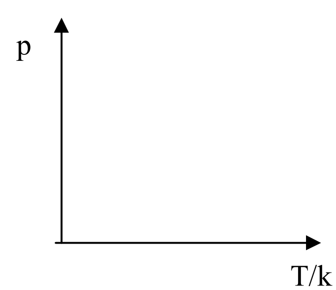


1.3. Pressure law

For a fixed mass of gas at constant volume, the pressure of the gas is **directly** proportional to its absolute temperature

$p \propto T$ if V and m constant

$\therefore \frac{p}{T} = \text{const}$ (T in kelvin)



1.4. Amount law
At a constant volume & temperature, the pressure of the gas is directly proportional to its amount of substance

$p \propto n$ if p and m constant
$\therefore \frac{p}{n}$ = const (T in kelvin)

2. Ideal gas equation pV = nRT

2.1 Combining the four gas laws, as mentioned above, for an ideal gas,

$pV \propto nT.$

The value of $\frac{pV}{T}$ is directly proportional to the amount of gas in moles *n*

$$\frac{pV}{T} \alpha \ n$$

$$\boxed{\mathbf{pV = nRT}} \quad \text{------- (1)}$$

where constant R is the universal molar gas constant = 8.31$JK^{-1}mol^{-1}$

$$\boxed{\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}} \quad \text{------- (2)}$$

where 1 refers to the original state of the gas (e.g. before heating) and 2 refers to its final state (e.g. after heating). T is always measured in Kelvin. The equation is used for the **same amount** of gas in two different states.

Why T must be measured in Kelvin?
It is because zero temperature, as measured in Kelvin, is the absolute zero.
Absolute zero is the temperature at which it is no longer possible to extract any energy from a system. This corresponds to the temperature at which a gas no longer has a volume or exerts any pressure. As ideal gases do not exist, this is a purely theoretical concept.

2.2 Hence, ideal gas obeys the ideal gas equation pV = nRT **at all values** of pressure P, volume V and absolute temperature T. It obeys kinetic theory of gas as well.

2.3 Define one mole of a substance: amount of substance contains number of particles which is equal to N_A which is 6.02 x 10^{23}.

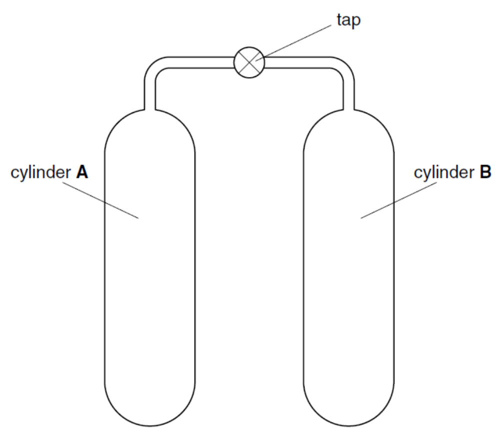
n = m/M (m and M are mass and molar mass of the gas respectively)
n = N/N_A (N and N_A are no. of gas molecules and no. Avogadro respectively)

Questions:

1. During the combustion stroke of an internal combustion engine the volume of the gas in the cylinder is reduced from 4.0×10^{-4} m^3 to 5.0×10^{-5} m^3. During the stroke, the pressure changes from 1.0×10^5 Pa to 18×10^5 Pa. If the temperature of the gas at the start of the stroke is 22 ^{o}C, what will be its temperature at the end of the stroke? [391^{o}C] [3]

2. Standard atmospheric pressure and temperature (stp) are 1.01×10^5 Pa and 0 ^{o}C. Determine the volume at stp of a mass of air which has a volume of 6.0×10^{-6} m^3 at a pressure of 3.41×10^5 Pa and a temperature of 400 ^{o}C. [8.22×10^{-6} m^3] [3]

3. Two insulated gas cylinders **A** and **B** are connected by a tube of negligible volume, as shown below.



Each cylinder has an internal volume of 5.0×10^{-2} m^3. Initially, the tap is closed and cylinder **A** contains 3.1 mol of an ideal gas at a temperature of 37 °C. Cylinder **B** contains the same ideal gas at pressure 2.6×10^5 Pa and temperature 37 °C.

(i) Calculate the amount, in mol, of the gas in cylinder **B**. [5.04 mol]

(ii) The tap is opened and some gas flows from cylinder **B** to cylinder **A**. Using the fact that the total amount of gas is constant, determine the final pressure of the gas in the cylinders. [2.10×10^5 Pa]