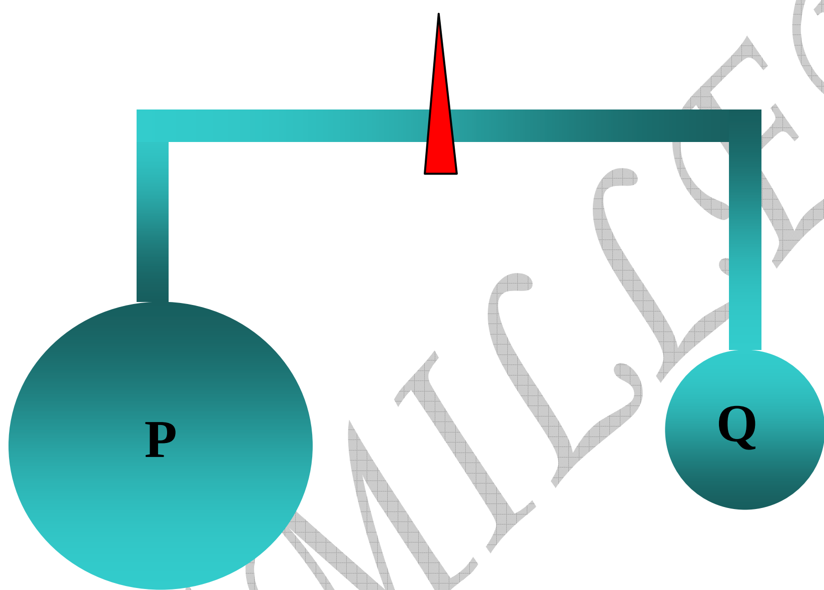
## *Gas Laws. Ideal Gas Equation*

### Gas Laws

### Two Connected Vessels and Gas Laws

A bulb P has a volume of 300cm$^3$ and a bulb Q a volume of 100cm$^3$. An ideal gas in P has a pressure of 2.0 x 10$^5$ Pa at 27°C and a similar gas in Q has a pressure of 1.0 x 10$^5$ Pa and temperature 127°C.When the tap T is operated, the two gases mix. Calculate the final steady pressure of the mixture if both bulbs P and Q are then maintained at 77$^0$C.




**Total number of moles in P and Q remain constant**

**Since pV = nRT, n = pV/RT. So if p is the final pressure,**

$$\frac{2 \times 10^5 \times 300}{R \times 300} + \frac{1 \times 10^5 \times 100}{R \times 400} + p \times \frac{(300 + 100)}{R \times 350}$$

**changing temperatures in °C to kelvin K.**

$$\text{Thus } 2 \times 10^5 + 0.25 \times 10^5 = p \times \frac{400}{350}$$

**Solving p = 1.97 x 105 Pa (approx)**

## Problems

1. A given mass of gas has a volume of $144 cm^3$ at 15°C.
Calculate its volume at (i) 33°C, (ii) 0°C, (iii) -67°C, the pressure being constant.

***Ans: i. 153 $cm^3$ ii. 137 $cm^3$ iii. 103 $cm^3$***

2. The pressure of a given mass of gas at 27°C is 750.0 mmHg.
If the volume remains constant, calculate the pressure at (i) 12°C, (ii) 0°C, (iii) -50°C.

***Ans: i. 712.5 ii. 682.5 iii. 557.5mmHg***

3. A mass of gas has a volume of 22.0 litres at 19°C and pressure $1.1 x 10^5$ Pa. What is the volume at 0°C and pressure $1.0 x 10^5$ Pa.?

***Ans: 22.6L***

4. A mass of gas has a volume of 30.0 litres at 17°C and $1.0 x 10^5$ Pa.
What is the pressure at 127°C when the volume is 25.0 litres?

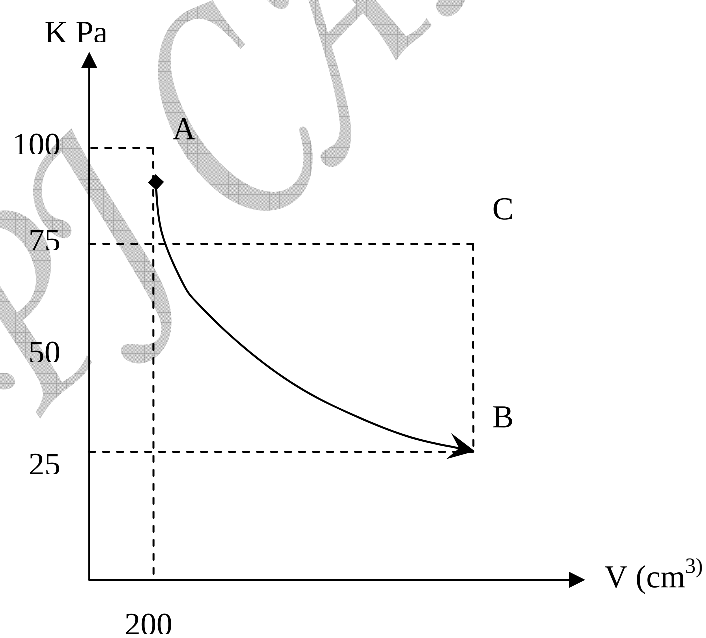
***Ans: 1.7 X $10^5$ Pa***

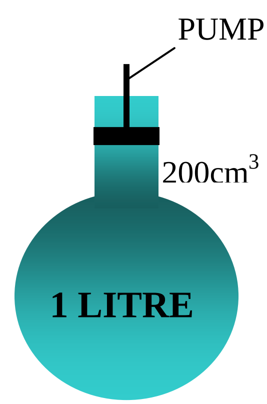
5. Calculate the mass of air which has a volume of $300 cm^3$ at $15^0$C and $1.1 x 10^5$ Pa if the density of air at 0°C and $1.0 x 10^5$ Pa is 1.30 $kgm^{-3}$.

***Ans: 0.4g***

6. A gas has a pressure of l00KPa, a volume of $200 cm^3$ and a temperature of 27°C. The gas is expanded at constant temperature to B, where the new pressure is 25 kPa. Calculate the new volume.
The gas is then heated at constant volume until its pressure is 75 kPa at C. Calculate the new temperature of the gas.

***Ans: $800 cm^3$, $627^0$C***



7 A pump is used to exhaust a vessel of volume 1 litre containing air at 1.2 atmospheres, at constant temperature. The pump has an effective volume of $200 cm^3$ and at each stroke this volume of air is expelled to the atmosphere.
(a) Calculate the reduced pressure in the vessel after one pump stroke. (b) Find the number of strokes needed to reduce the pressure to 0.01 atmospheres.
(*Hint: The air expands* $200 cm^3$ *when the pump piston is raise.*)

***Ans: a. 1atm   b. 60 strokes***

## The ideal gas equation

8. Calculate the molar gas constant if 1mole of a gas has a volume $22.4 \times 10^{-3}$ $m^3$ at $0^oC$ and $1.013 \times 10^5$ Pa.

***Ans: 8.31JK$^{-1}$mol$^{-1}$***

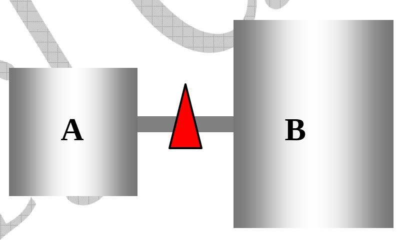
9. Helium has a pressure of $0.9 \times 10^5$ Pa and a temperature of $27^0C$ in a vessel of volume 4 litres ($4 \times 10^{-3}$ $m^3$). Calculate (i) the number of moles of the gas, (ii) its mass.
*(R = 8.3 J K$^{-1}$ mol$^{-1}$, molar mass of helium = 4 g.)*

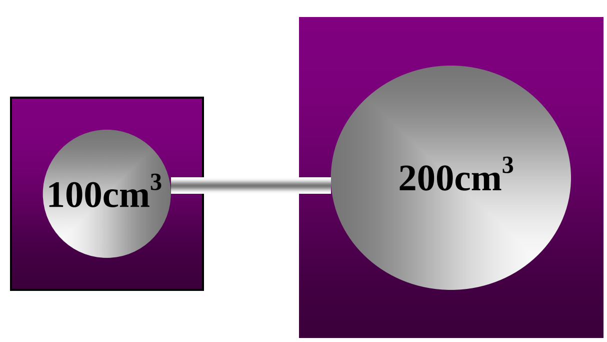
***Ans: i. 0.14mol  ii. 0.58g***

10. For three different cases of an ideal gas, the equation of state may be expressed by (a) pV= RT, (b) pV= nRT, and (c) pV= mRT/M, where R is the molar gas constant and M is the mass of one mole.
(i) What is the number of moles used in (a), (b) and (c) respectively?
(ii) In (c), what does m represent?
(iii) If $N_A$ is the Avogadro constant, $6.0 \times 10^{23}$ $mol^{-1}$, write down the equation of state for an ideal gas containing N molecules.

***Ans: i. 1, n***

11. Calculate the number of moles in a gas which has a volume of $6 \times 10^{-3}$ $m^3$ at a pressure of $1 \times 10^5$ Pa and temperature of 300 K. *(Molar gas constant = 8.3 J mol$^{-1}$ K$^{-1}$).*



***Ans: 0.24 mol***

12. Two vessels A and B at the same temperature are connected by a valve. Initially A contained 3 litres of oxygen gas at 60 kPa pressure and B contained 5 litres of nitrogen at 40 kPa. Calculate the final steady pressure in A and B.

***Ans: 4.75 X $10^4$Pa***

13. Oxygen gas is contained in a vessel of volume 0.05 $m^3$ at a temperature of 17°C and pressure 2.0 x $10^5$ Pa. When some of the gas is used, the pressure in the vessel falls to 0.8 x $10^5$ Pa and the temperature remains17°C. Calculate the mass of oxygen used.

*(Molar gas constant = 8.3J$mol^{-1}$ $K^{-1}$ mass of 1 mole oxygen = 0.032 kg.)*

***Ans: 0.08Kg.***

14. Write down a formula for the number of moles of a gas in terms of its pressure (p), volume (V), absolute temperature (T), and molar gas constant (R). A glass bulb of 100 $cm^3$ is connected to another bulb of 200$cm^3$ by a narrow tube of negligible volume. The apparatus contains air at 17°C and 90.0 kPa pressure. The smaller bulb is then maintained at 57°C, the temperature of the other bulb remaining at 17°C. Calculate the new pressure in the apparatus.

(Hint. The total number of moles in the two bulbs remains constant.)

***Ans: 93.8 kPa.***

15 In Question 14, calculate the pressure if the smaller bulb is finally maintained at 100°C and the larger bulb 27°C

***Ans: 99.6 kPa*.**