Ideal Gas Law

Recall:

1)Avogadro's Law $V=K_A n$

2)Boyle's Law $P = \frac{K_B}{V}$

3)Charles' Law $V = K_C T$

4)Gay-Lussac's Law $P = K_G T$

Solving for K in each equation gives:

1) $K_A = \frac{V}{n}$ 2) $K_B = PV$ 3) $K_C = \frac{V}{T}$ 4) $K_G = \frac{P}{T}$

We can lump all of the Ks together into one constant and call it 'R'

$$R = \frac{PV}{nT}$$

'R' is called the Ideal Gas Constant

Ideal Gas Equation: PV = nRT

At STP, $P_1 = 101.3\ kPa$ $n = 1\ mole$

$T_1 = 273\ K$ $V = 22.4\ L$

$$R = \frac{PV}{nT} \quad R = \frac{(101.3kPa)(22.4L)}{(1mol)(273K)} \quad R = 8.31 \frac{kPa \cdot L}{mol \cdot K}$$

*note: when using this R value in PV=nRT calculations, P must be in kPa, V must be in Liters, and T must be in Kelvin.

e.g. 16.72 L of O_2 gas at a temperature of -87.5°C exerts a pressure of 297 kPa. What mass of O_2 is present in this sample?

We can deduce the number of moles present by means of the ideal gas equation and then use the molar mass of O_2 to find the mass of O_2 in the sample.

P = 297 kPa   T = 185.5 K

V = 16.72 L   R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$

$$PV = nRT \quad (297kPa)(16.72L) = (n)\left(8.31 \frac{kPa \cdot L}{mol \cdot K}\right)(185.5K)$$

$$n = 3.22 \text{ mol}$$

$$M_{O_2} = 2(16.00g/mol)$$
$$= 32.00g/mol$$

1 mole O_2 = 32.00g (c.f. derived from molar mass of O_2)

$$3.22 \text{ mol } O_2 \times \frac{32.00g}{1 \text{ mol}} = 103.4g\ O_2$$

∴ 103.4g of $O_{2(g)}$ is present in the 16.72 L sample with a pressure of 297 kPa at a temperature of -87.5°C

(note: temperature had to be converted from Celsius to Kelvin)

ex. What is the molar mass of a gas if 108.5g of this gas occupies 8.63 L at 440 kPa and a temperature of -104.5°C?

$P = 440\ kPa$ $T = 168.5\ K$

$V = 8.63\ L$ $R = 8.31 \frac{kPa \cdot L}{mol \cdot K}$

$$PV = nRT \quad (440 kPa)(8.63 L) = (n)\left(8.31 \frac{kPa \cdot L}{mol \cdot K}\right)(168.5 K)$$

$$n = 2.71\ mol$$

2.71 mol = 108.5g (c.f. derived from calculations)

$$1\ mol\ unknown_{(g)} \times \frac{108.5g}{2.71\ mol} = 40.0g\ of\ unknown_{(g)}$$

∴ the unknown gas has a molar mass of 40.0g/mol