Thermochemical equations – and PV = nRT

Lesson 9

1) Density is given as mass / volume

a) Using the equation PV = nRT obtain an expression for the density of a gas.

Refer to the link above for transformation of the ideal gas equation.

=> PV=nRT

=> PV=(m/M)RT = mRT/M

=> PM=mRT/V = PM=dRT ------ Where d = m/V density (g/L)

=> d = PM/RT

b) What is the density, in g / mL, of Cl_2 gas at 120.00 ^oC and 1.00 atm pressure?

Step 1 change the units

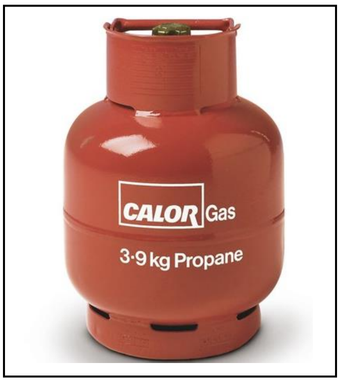
=> T = (120.00 + 273)=393^{o}K,

P = (1.00/0.987) X 100 kPa = 101.3kPa, Check conversions from Data Booklet

M (Cl_2) = 71.0g

=> d = 101.3 X 71.0 / (8.31 X 393) = 2.20g/L = 2.20 X 10^{-3}g/mL

c) The propane gas cylinder, shown on the right, was left outside at a temperature of 40.0 ^oC. If the container was full of propane, as per label, what was the pressure exerted on the walls of the container by the propane gas if the cylinder has a volume of 9.00 litres? Assume all the propane is in the gaseous state.



Step 1 Find the mol of propane

=> 3900 g / 44.1 = 88.435

Step 2 Calculate the pressure in kPa

=> P = nRT/V

=> P = 88.435 X 8.31 X 313 / 9.00

=> P = 2.6 X 10^4 kPa (2 sig figs as the mass of propane is given to 2 sig figs)

2) a) Write a balanced thermochemical equation for the complete combustion of liquid octane.

$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H = -10920$kJ/mol

Molar heat of combustion of octane is obtained from the Data Booklet at 5460 and double since two mol of octane is shown to combust in the equation. Note the molar heat of combustion given in the Data Book assumes that water is in the liquid state.

b) When an unknown amount of octane burns completely in excess oxygen 54.64 kJ of energy is released. What volume of carbon dioxide is produced at 100^{o}C and at a pressure of 150.0 kpa?

Step 1 fined the mol of CO_2 produced when 54.64 kJ of energy is released.

=> Apply the ratio as per the equation

=> mol of CO_2 / energy = 16 / 10920 = n / 54.64

=> n = 8.006 X 10^{-2}mol

Step 2 Calculate the volume of CO_2

=> V =nRT/P = 0.08006 X 8.31 X 373 / 150.0 kPa = 1.65L (3 sig figs)

c) What mass of octane must undergo complete combustion in order to produce 4.00 X 10^3 litres of carbon dioxide at 100^oC and 1.20 atm pressure?

Step 1 – Calculate the mol of CO_2 produced

=> n = PV/RT (Convert all units. Use the Data book))

=> n = 121.6 X 4.00 X 10^3 / (8.31 X 373) = 156.9mol

Step 2 Apply the stoichiometric ratio, as per equation, to find the mol of octane that must have reacted.

=> (2/16) X 156.9 = 19.61 mol

Step 3 Find the mass of octane.

=> m = Fm X mol = 114.23 X 19.62 = 2.24 kg of octane (3 sig figs)

d) i. What amount of energy is released in, MJ, if octane burns in excess oxygen to produce 1.84 X 10^4 litres of CO_2 gas at SLC.

Step 1 Find the mol of carbon dioxide that is produced

=> Since it is at SLC we can apply the formula $n_{carbon\ dioxide}$ = 18400 / 24.8 = 741.9 mol

Step 2 Find the energy produced in kJ

=> Apply the stoichiometric ratio as per equation

=> 16/10920 = 741.9/energy

=> energy = 741.9 X 10920/16 = 5.06 X 10^5kJ = 506 MJ (3 sig figs) (conversion of kJ to MJ is given in the Data booklet.

ii. Give the amount of energy produced in MJ per litre of CO_2 produced.

506 /(1.84 X 10^4) = 2.75 X 10^{-2} MJ/L