Applying Dalton's Law of Partial Pressures

John Dalton was the first to observe:

The total pressure of a mixture of gases equals the sum of the partial pressure of each gas in the mixture.

$P_{TOTAL} = P_1 + P_2 + P_3 + \ldots$ (P_1, P_2) = Partial pressure of each gas.

The partial pressure of a gas is the pressure that the gas would exert if it were the only gas in the container.

Partial pressure of a gas is independent of the type of the gas itself, BUT is dependent on the number of moles of gas particles present.

$$\frac{\text{mols of gas 1, } n_1}{\text{Total mols, } n_T} = \frac{\text{partial press. of gas 1, } P_1}{\text{Total pressure, } P_T}$$

therefore:

$$\text{Partial pressure of gas 1, } P_1 = \left(\frac{\text{mols gas 1, } n_1}{\text{Total mols, } n_T}\right) . P_T$$

$$\text{Partial pressure of gas 1, } P_1 = (\text{Mole fraction of gas 1}) . P_T$$

$$P_1 = \frac{n_1}{n_T} . P_T$$

Also we can use the ideal gas equation:

$$P_T V = n_T R T$$

P_T = sum of partial pressures of the gaseous mixture.
n_T = total number of mols of all gases present in the mixture.

The law of partial pressures has many applications, it is frequently used to determine the amount of a water-insoluble gaseous reaction product or slightly soluble gas, such as hydrogen, oxygen. The gaseous product is collected over water, i.e. by being bubbled through water into an inverted container.

A common way to determine the amount of gas present is by collecting it over water and measuring the height of displaced water; this is accomplished by placing a tube into an inverted bottle, the opening of which is immersed in a larger container of water. As the gas bubbles into the test tube it displaces the water until the test tube is full. The collected gas is not the only gas in the test tube, the, since liquid water is always in equilibrium with its vapour, so the collected gas in the test tube is a mixture of two gases : the gas being collected and the water vapour.

The partial pressure of water is known as the vapor pressure of water and is dependent on the temperature. Thus, the volume of gas collected consists of a mixture of the gas collected and the water vapour, and the total pressure is the sum of the two contributing partial pressures

From a list of water vapour pressure values at various temperatures , the value of the pressure of the dry gas collected is found by the vapor pressure of water being subtracted from the total vapor pressure of the gas mixture; (equalizing the atmospheric pressure to give the partial pressure of the gaseous product collected).
With volume and temperature known, the mount of gaseous product can be determined.

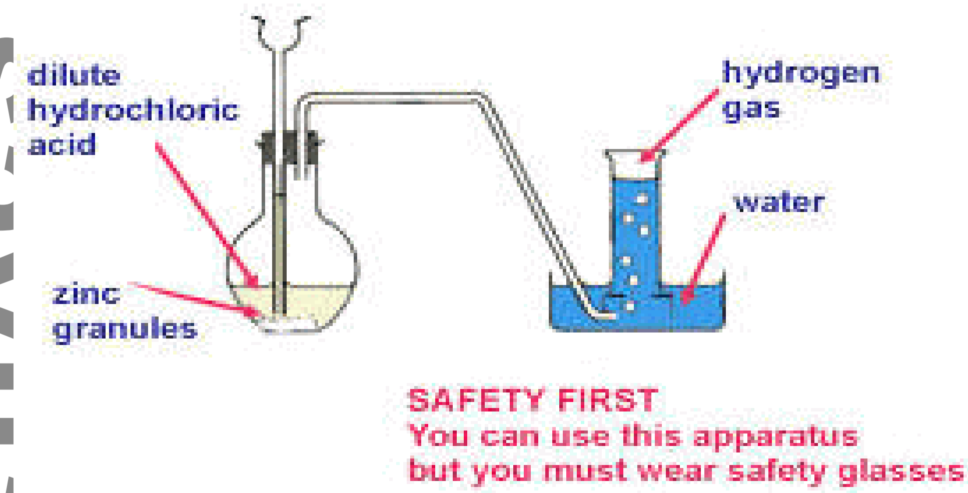
Vapour Pressure of Water at Various Temperatures

Temperature (ºC)	Vapour Pressure (kPa)	Temperature (ºC)	Vapour Pressure (kPa)
0	0.61	26	3.36
5	0.87	27	3.57
10	1.23	28	3.78
15	1.71	29	4.00
16	1.82	30	4.24
17	1.94	35	5.62
18	2.06	40	7.38
19	2.20	45	9.58
20	2.34	50	12.33
21	2.49	60	19.92
22	2.64	70	31.16
23	2.81	80	47.34
24	2.98	90	70.10
25	3.17	100	101.3

Problem

A small piece of zinc reacts with dilute hydrochloric acid to form hydrogen gas, which is collected over water at 16.0 ^{O}C. The total pressure is adjusted to barometric pressure , 100.24 kPa, and the volume of hydrogen gas is measured as 1495 cm^3. Calculate:

a. The partial pressure of the hydrogen gas,
b. The mass of the hydrogen gas.



Answer

a. partial pressure of hydrogen gas = 100.24 kPa - 1.82 kPa = 98.42 kPa

b. $V = 1.495$ L, $T = 289$ K, $M_R = 2.016$ g mol^{-1}

$PV = nRT$ $\qquad\qquad$ $m = n M_R$

Hence: mass of hydrogen gas = 0.123 g

Assignment

1. Acetylene, C_2H_2, an important fuel in welding is produced by the reaction of calcium carbide , CaC_2, with water:

$$CaC_{2,(s)} + 2H_2O_{(l)} \longrightarrow C_2H_2, + Ca(OH)_{2(aq)}$$

A sample of acetylene was collected over water, the total gas pressure was adjusted to barometric pressure, 99.98 kPa, and the volume of acetylene was measured as 425 mL at a temperature of 26.0 ^{O}C. How many grams of acetylene was prepared?

2. A sample of sodium azide, NaN_3, a compound used in automobile air-bags was thermally decomposed, and 15.5 mL of nitrogen gas was collected over water at 27,0 ^{O}C and 103.5 kPa. How many grams of nitrogen were collected.