GAS DENSITY

(Last Revision: August 26, 2022)

- ABSTRACT:

  The method of gas density is used to determine the molecular weight of an unknown gas. The molecular weight is found by weighing a sample of gas in a known volume at a known pressure. An extrapolation procedure is used to find the molecular weight.

- TEXT REFERENCE:

  Ball, "Physical Chemistry", 2nd edition, 2015.

  Garland, et al., “Experiments in Physical Chemistry”, 8th edition, 2009.

- GENERAL DESCRIPTION AND THEORY:

  The ideal gas law is given by:

  $$PV = nRT = \frac{g}{M}\,RT\ ,$$

  where *P* is the pressure, *V* is the volume, *T* the temperature in Kelvins, *g* the mass of the gas, *R* the ideal gas constant and *M* the molar mass of the gas. This equation may be rearranged to give the density of the gas :

  $$\rho = \frac{g}{V} = \frac{MP}{RT}\ .$$

  Since the ideal gas law is only valid as the pressure approaches zero, an extrapolation procedure must be used to determine the molecular weight of a real gas. A convenient extrapolation is to plot ρ/P versus *P* (Where ρ is the gas density, g/V) and extrapolate to zero pressure to solve for the molecular weight.

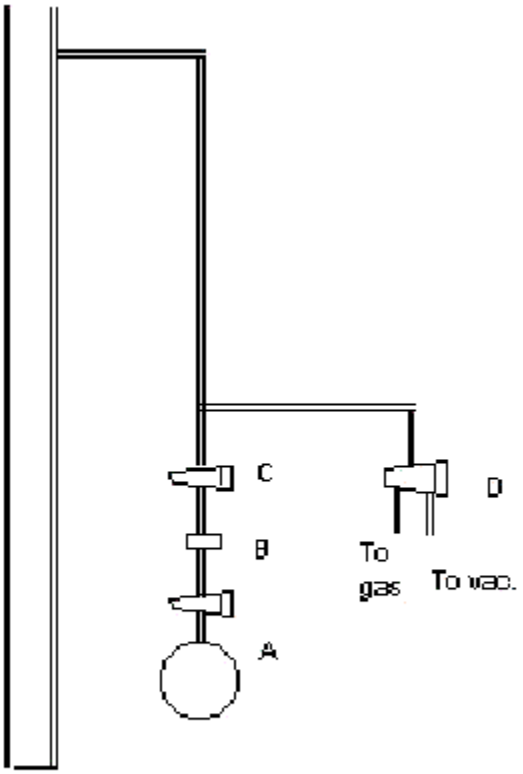
- EQUIPMENT:

  Manometer, gas bulb, gas manifold, vacuum pump.

- CHEMICALS:

  Unknown gas.

- DIAGRAMS:



- LABORATORY PROCEDURE:

  The gas is weighed in a glass bulb of the type shown in the figure. The bulb is first evacuated on the manifold using a vacuum pump to obtain a pressure of 1 mm Hg or less. The bulb is then filled with the gas at a measured pressure. The pressure is measured by reading the manometer. The barometer must also be read if an open end manometer is being used. In weighing the bulb a counterpoise should be used to compensate for buoyant effect of the air. If a counter poise is not used a buoyancy correction will have to be made. The bulb is weighed when evacuated and when filled with each of the pressures used.

  In weighing the bulb, the following procedure is used. The stopcock to the bulb is closed after reading the pressure in the system. The bulb is removed and wiped with a clean lintless damp cloth and allowed to hang in the balance case for 5 to 10 minutes to come to constant weight.

The bulb is filled with gas by first evacuating the system, by opening stopcocks at A, C and D, and then filling the system with the gas through the double stopcock, D. The pressure is measured when the two stopcock, D, is closed.

For a closed end manometer, the observed pressure in mm Hg is corrected to 0 ^{o}C by the equation:

$$P_0 = P - P\frac{[at - b(t - t_{s)}]}{(1 + at)} \quad ,$$

where P_o, P are, respectively, the corrected and observed pressures, t is the temperature of the manometer (°C), t_s is the temperature at which scale was calibrated, usually 20 ^{o}C, a is the mean cubical coefficient of expansion of mercury between 0 and 35 ^{o}C b is the linear coefficient of expansion of scale material. The value of a is 181.8×10^{-6}, and the value of b is 18.4×10^{-6} for brass and 5×10^{-6} for wood.

If an open end manometer is used, the pressure in the bulb is equal to the difference between the corrected barometric pressure and the manometer pressure corrected by the above equation. Don't forget to record the air temperature during each measurement.

The weights of the gas should be determined at four pressures going down to a pressure of about half an atmosphere. The volume of the bulb is found by filling the bulb with water at a known temperature and weighing the bulb. The density of the water can easily be found and the volume of the bulb determined.

- CALCULATIONS:

  If a counterpoise bulb of the same volume as the sample bulb was used no correction for buoyancy is needed. If no counterpoise bulb was used a correction for buoyancy must be made.

  The weight of gas is found by difference between the filled and evacuated bulb. The molecular weight of the gas can be calculated at each pressure. To determine the true molecular weight, plot the molecular weight at each pressure against the pressure and extrapolate to zero pressure.

- DATA

  The following data were obtained during the performance of this experiment:

  Barometric Pressure (corrected) = 740.2 Torr

  Temperature = 25.2 ^{o}C

A wood scale open end manometer was used.

A counterpoise bulb was used in the weighings.

Weight of bulb plus water = 207.2648 g

Trial	Wgt. Bulb empty (g)	Wgt. Bulb plus gas (g)	Manometer difference(mm Hg)
1	85.2653	86.0758	-20.1
2	85.2650	85.8738	132.5
3	85.2652	85.6506	360.4
4	85.2651	85.4124	588.6

NOTE: Negative pressure difference means the pressure is greater than the atmosphere.

Use the data given above to write a formal laboratory report as if you had performed the experiment in the laboratory. Turn the report in at the next period.