Gas Laws III
Dalton's Law of Partial Pressures
in Applied Calculations

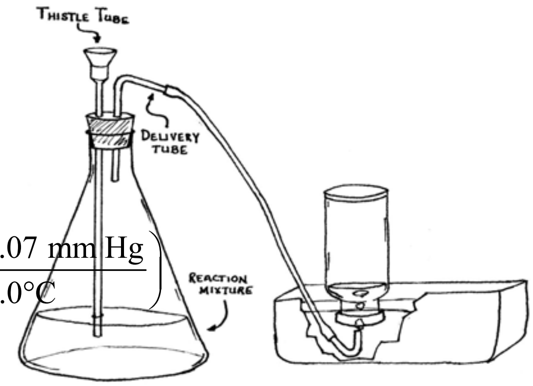
1. Air is about 78%$^v/_v$ N_2 and 21%$^v/_v$ O_2 (~1%$^v/_v$ Ar, CO_2, etc. total). Calculate the partial pressure (in mm Hg) of the oxygen gas and nitrogen gas when the total barometric pressure is 1003 mbar. (Recall that 1 atm = 1.01325 bar)

$$P_{O_2} = 0.21(1003 \text{ mbar}) = 210 \text{ mbar}$$
$$P_{N_2} = 0.78(1003 \text{ mbar}) = 782 \text{ mbar}$$

2. A scuba diver will often descend to 16 feet in the ocean where the pressure of the air being breathed is 1.5 atm. What is the partial pressure of the oxygen at this depth?

$$P_{O_2} = 0.21(1.5 \text{ atm}) = 0.32 \text{ atm}$$

3. Refer to the gas collection device pictured. What is the partial pressure of the hydrogen gas in the gas collection bottle obtained when the water in the bottle is displaced by hydrogen from the reaction of zinc with hydrochloric acid? The volume of the bottle was measured to be 165 mL, the temperature of the equipment is assumed to be room temperature (23.2°C), and the barometric pressure is 751.9 mm Hg. It may be necessary to estimate or use an approximate value for the vapor pressure of water at this temperature.



Interpolate the vapor pressure of H_2O:

$$P_{H_2O} = 21.07 \text{ mm Hg} + (23.2°C - 23.0°C)\left(\frac{22.39 \text{ mm Hg} - 21.07 \text{ mm Hg}}{24.0°C - 23.0°C}\right)$$

$$= 21.33 \text{ mm Hg}$$

$$P_{gas} = 751.9 \text{ mm Hg} = P_{H_2} + P_{H_2O}$$

$$P_{H_2} = 751.9 \text{ mm Hg} - 21.33 \text{ mm Hg} = 730.6 \text{ mm Hg}$$

4. What is the volume of the H_2 produced if the water vapor is removed?

$$V_{gas} = 165 \text{ mL}$$

$$f_{H_2} = \frac{730.6 \text{ mm Hg}}{751.9 \text{ mm Hg}} = 0.9716$$

$$V_{H_2} = 0.9716 \tfrac{\text{L H}_2}{\text{L gas}} (165 \text{ mL}) = 160\ (\pm 1) \text{ mL}$$

5. Nitroglycerin explodes according to the equation

$$4\ C_3H_5N_3O_{9(l)} \rightarrow 12\ CO_{2(g)} + 10\ H_2O_{(g)} + 6\ N_{2(g)} + O_{2(g)}$$

What is the total pressure in a 1.0 L closed rigid container (perhaps a hole in the rock in a mine) when 200.0 g of nitroglycerine explodes. Assume for the problem that the temperature of the produced gases are 850°C.

$$V = 1.0\text{ L} \qquad T = 850°\text{C} + 273\text{ K} = 1123\text{ K}$$

$$n_{\text{NG}} = {}^{200.0\text{ g}}\!\!\diagup_{227.09\,\frac{\text{g}}{\text{mol}}} = 0.8807\text{ mol NG}$$

1) either calculate the moles of each, sum them, and calc pressure, or
   realizing that all products are gases,
2) calculate total moles of products in one step and calc pressure

$$n_{\text{gas products}} = 0.8807\text{ mol NG} \times \frac{29\text{ mol products}}{4\text{ mol NG}} = 6.385\text{ mol products}$$

$$P = \frac{nRT}{V} = \frac{(6.385\text{ mol})(0.08206\,\frac{\text{L·atm}}{\text{mol·K}})(1123\text{ K})}{1.0\text{ L}} = 588\text{ atm (w/o regard to correct SFs)}$$

Vapor Pressure of Water
at Several Temperatures

Temperature (°C)	**Vapor Pressure (mm Hg)**
15.0	12.79
16.0	13.63
17.0	14.53
18.0	15.48
19.0	16.48
20.0	17.54
21.0	18.65
22.0	19.83
23.0	21.07
24.0	22.39
25.0	23.76
26.0	25.21
27.0	26.74
28.0	28.35
29.0	30.04
30.0	31.82

Gas Laws III
Dalton's Law of Partial Pressures
Additional Problems

1. The amount of NO_2 on a very smoggy day in Houston, TX was measured to be 0.78 ppmv (parts-per-million by volume). The barometric pressure was 1011 mbar. Calculate the partial pressure of the NO_2.

$$C_{NO_2} = \frac{0.78 \text{ L NO}_2}{10^6 \text{ L air}}$$

$$P_{NO_2} = \frac{0.78 \text{ L NO}_2}{10^6 \text{ L air}}(1011 \text{ mbar}) = 0.000789 \text{ mbar} = 7.9\times10^{-4} \text{ mbar}$$

2. A mixture of cyclopropane gas (C_3H_6) and oxygen gas in a 1.00:4.00 mol ratio is uncommonly used as an anesthetic gas. What mass of each gas is present in a 2.00 L steel container pressurized to 150.0 bar at 25.0°C?

$$f_{C_3H_6} = \frac{1.00 \text{ mol C}_3\text{H}_6}{5.00 \text{ mol gas}} = 0.200\,\tfrac{\text{mol C}_3\text{H}_6}{\text{mol gas}}$$

$$f_{O_2} = 0.800\,\tfrac{\text{mol O}_2}{\text{mol gas}}$$

$$P_T = 150.0 \text{ bar} \big/ 1.01325\,\tfrac{\text{bar}}{\text{atm}} = 148.0 \text{ atm}$$

$$T = 298.2 \text{ K}$$

$$V = 2.00 \text{ L}$$

$$n_T = \frac{PV}{RT} = \frac{(148.0 \text{ atm})(2.00 \text{ L})}{(0.08206\,\tfrac{\text{L·atm}}{\text{mol·K}})(298.2 \text{ K})} = 12.10 \text{ mol gas}$$

$$m_{C_3H_6} = 12.10 \text{ mol gas}\times(0.200\,\tfrac{\text{mol C}_3\text{H}_6}{\text{mol gas}})\times42.081\,\tfrac{\text{g}}{\text{mol}} = 101.8 \text{ g C}_3\text{H}_6$$

$$m_{O_2} = 12.10 \text{ mol gas}\times(0.800\,\tfrac{\text{mol C}_3\text{H}_6}{\text{mol gas}})\times32.00\,\tfrac{\text{g}}{\text{mol}} = 309.8 \text{ g O}_2$$

3. "Mixed-air" divers often use standard air (78%N_2, 21%O_2, 1%Ar) which has been enriched to 32%O_2. As the dive tender aboard a marine science research vessel, it is your responsibility to fill scuba tanks with the proper air mix. A 12.5 L (internal volume) scuba tank is pressurized to 2550 psi with standard air. You add pure oxygen to the tank. What must the final pressure be so that the air has a composition of 32%O_2? All measurements are made at 25.0°C.

Presented is a very straight-forward, but not entirely intuitive, way to the solution. Study the solution strategy carefully.

$$P_{O_2} = 0.21(2550 \text{ psi}) = 535.5 \text{ psi}$$
$$P_{N_2,\text{etc}} = 2014.5 \text{ psi}$$
$$2550 \text{ psi} = P_{N_2,\text{etc}} + P_{O_2}$$

$$2550 \text{ psi} + P_{O_2}^{\text{new}} = P_{N_2,\text{etc}} + (P_{O_2} + P_{O_2}^{\text{new}})$$
$$2550 \text{ psi} + P_{O_2}^{\text{new}} = P_{N_2,\text{etc}} + (535.5 \text{ psi} + P_{O_2}^{\text{new}})$$

$$0.32 \frac{\text{psi } O_2}{\text{psi air}} = \frac{P_{O_2} + P_{O_2}^{\text{new}}}{2550 \text{ psi} + P_{O_2}^{\text{new}}} = \frac{535.5 \text{ psi} + P_{O_2}^{\text{new}}}{2550 \text{ psi} + P_{O_2}^{\text{new}}}$$

$$2550 \text{ psi} + P_{O_2}^{\text{new}} = P_{N_2,\text{etc}} + 0.32 \frac{\text{psi } O_2}{\text{psi air}} (2550 \text{ psi} + P_{O_2}^{\text{new}})$$

$$0.68 P_{O_2}^{\text{new}} = 280.5 \text{ psi}$$
$$P_{O_2}^{\text{new}} = 412.5 \text{ psi}$$

$$P_{T}^{\text{new}} = 2550 \text{ psi} + 412.5 \text{ psi} = 2963 \text{ psi}$$