Getting the other gas laws

If temperature is constant you get Boyle's Law

$$P_1V_1 = P_2V_2$$

If pressure is constant you get Charles's Law

$$\frac{V_1}{T1} = \frac{V2}{T_2}$$

If volume is constant you get Gay-Lussac's Law

$$\frac{P_1}{T_1} = \frac{P2}{T_2}$$

If all are variable, you get the Combined Gas Law.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Boyle's Law:

Inverse relationship between **Pressure** and **Volume**.

$$P_1V_1 = P_2V_2$$

P

V

Combined Gas Law:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Gay-Lussac's Law:

Direct relationship between **Temperature** and **Pressure**.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Charles' Law:

Direct relationship between **Temperature** and **Volume**.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

(T must be in Kelvin)

T

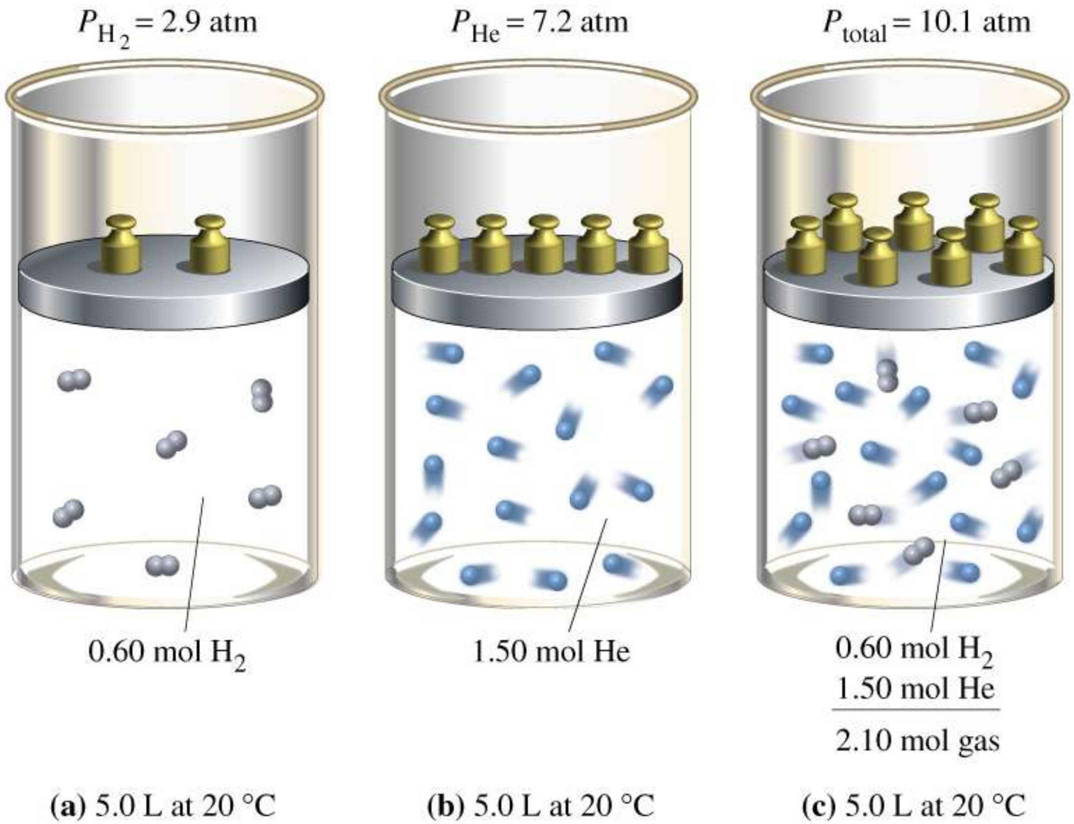
Dalton's Law of Partial Pressures

- He found that in the absence of a chemical reaction, the pressure of a gas mixture is the sum of the individual pressures of each gas alone
- The pressure of each gas in a mixture is called the **partial pressure** of that gas
- ***Dalton's law of partial pressures*** → *the total pressure of a mixture of gases is equal to the sum of the partial pressures of the component gases*
- The law is true regardless of the number of different gases that are present
- Dalton's law may be expressed as

$$P_T = P_1 + P_2 + P_3 + \ldots$$

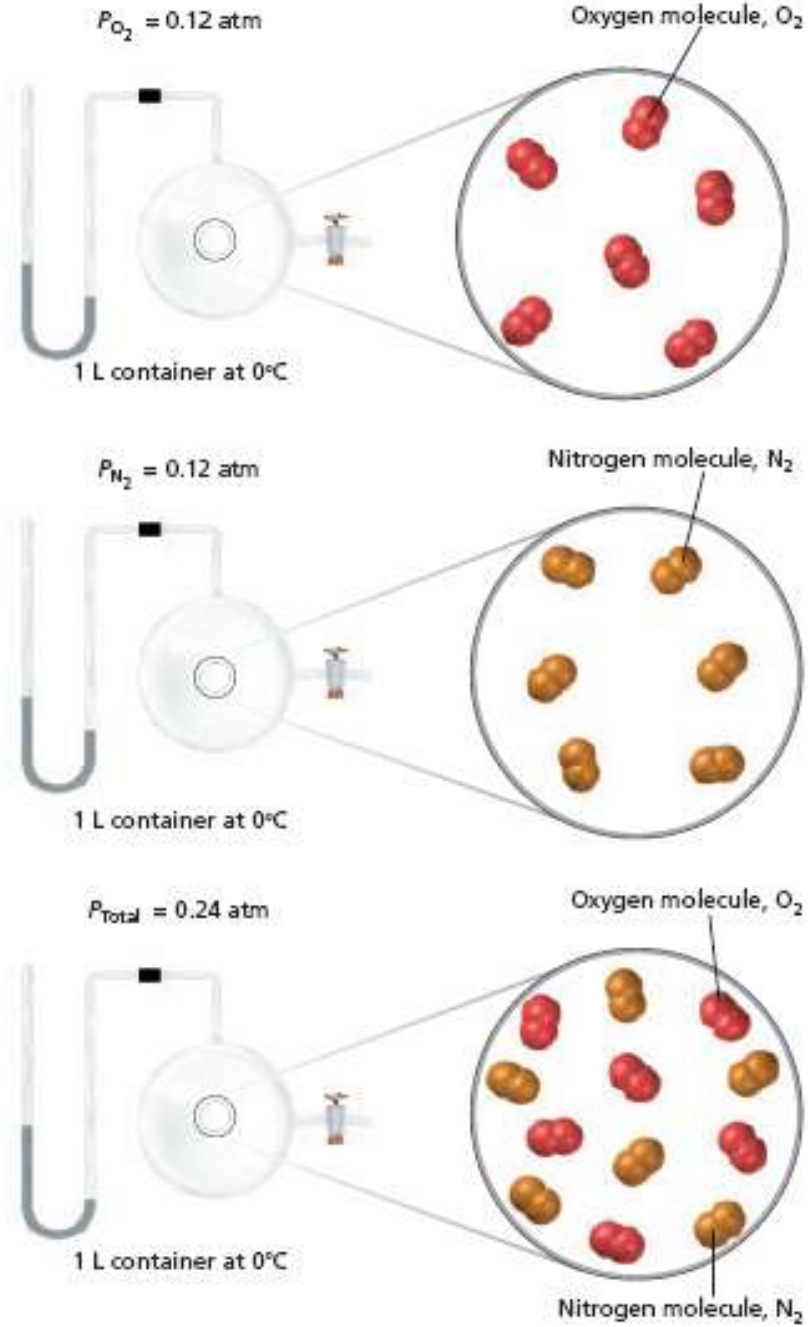
Dalton's Law of Partial Pressures

What is the total pressure in the cylinder?



P_{total} in gas mixture = $P_1 + P_2 + \ldots$

Dalton's Law: total P is sum of pressures.

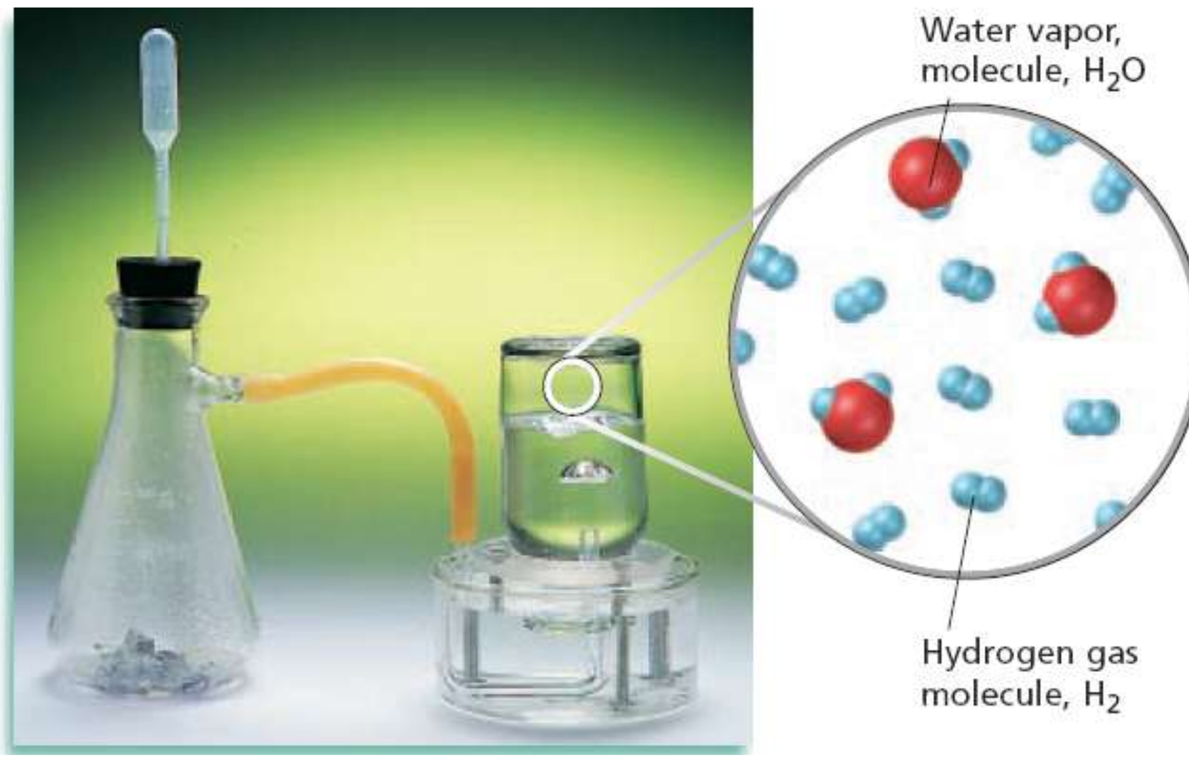


IGURE 10-14 Samples of oxygen gas and nitrogen gas are mixed. he total pressure of the mixture is the sum of the pressures of the gases.

Gases Collected by Water Displacement

- Gases produced in the laboratory are often collected over water

FIGURE 10-15
Hydrogen can be collected by water displacement by reacting zinc with sulfuric acid. The hydrogen gas produced displaces the water in the gas collecting bottle. It now contains some water vapor.



Dalton's Law of Partial Pressures

- The gas produced by the reaction displaces the water, which is more dense, in the collection bottle
- You can apply Dalton's law of partial pressures in calculating the pressures of gases collected in this way
- A gas collected by water displacement is not pure but is always mixed with water vapor
- That is because water molecules at the liquid surface evaporate and mix with the gas molecules
- Water vapor, like other gases, exerts a pressure, known as *water-vapor pressure*

Dalton's Law of Partial Pressures

- Suppose you wished to determine the total pressure of the gas and water vapor inside a collection bottle
- You would raise the bottle until the water levels inside and outside the bottle were the same
- At that point, the total pressure inside the bottle would be the same as the atmospheric pressure, P_{atm}
- According to Dalton's law of partial pressures, the following is true

$$P_{atm} = P_{gas} + P_{H_2O}$$

Dalton's Law of Partial Pressures

Table 18-2

Vapor Pressure of Water

Temperature (°C)	Pressure (kPa)	Temperature (°C)	Pressure (kPa)	Temperature (°C)	Pressure (kPa)
0	0.6	21	2.5	30	4.2
5	0.9	22	2.6	35	5.6
8	1.1	23	2.8	40	7.4
10	1.2	24	3.0	50	12.3
12	1.4	25	3.2	60	19.9
14	1.6	26	3.4	70	31.2
16	1.8	27	3.6	80	47.3
18	2.1	28	3.8	90	70.1
20	2.3	29	4.0	100	101.3

Dalton's Law of Partial Pressures

- Oxygen gas from the decomposition of potassium chlorate, $KClO_3$, was collected by water displacement. The barometric pressure and the temperature during the experiment were 731.0 mmHg and 20.0°C, respectively. What was the partial pressure of the oxygen collected?
- **Given:**
  - $P_{H_2O} = 17.5\ mmHg$ *(vapor pressure of water at 20.0°C)*
  - $P_T = P_{atm} = 731.0\ mmHg$
  - $P_{atm} = P_{O_2} + P_{H_2O}$
- **Unknown:** P_{O_2} in mmHg

$$P_{O_2} = P_{atm} - P_{H_2O}$$

$$P_{O_2} = 731.0\ mmHg - 17.5\ mmHg = 713.5\ mmHg$$

Dalton’s Law of Partial Pressures

Some hydrogen gas is collected over water at 20.0°C. The levels of water inside and outside the gas-collection bottle are the same. The partial pressure of hydrogen is 742.5 mmHg. What is the barometric pressure at the time the gas is collected?

- *Answer* 760.0 mmHg

Dalton's Law of Partial Pressures

Helium gas is collected over water at 25°C. What is the partial pressure of the helium, given that the barometric pressure is 750.0 mm Hg?

- *Answer* 726.2 mm Hg

Avogadro's Law

At fixed temperature and pressure, equal volumes of any ideal gas contain equal number of particles (or moles).

$V/n = \text{constant}$

Or…

At STP, one mole of any gas will occupy 22.4 L of space, regardless of the mass of the particles. This can be used as a conversion factor:

For a gas at STP, **1 mol = 22.4 L**

The Ideal Gas Law

P = Pressure

V = Volume

T = Temperature

n = number of moles

$$PV = nRT$$

R is a constant, called the Ideal Gas Constant

$$R = 0.0821 \frac{(L)(atm)}{(K)(mol)}$$

$$R = 8.31 \frac{(L)(kPa)}{(K)(mol)}$$

Ideal Gas Law allows us to calculate one variable if the other 3 are known; does not require "initial" and/or "final" measurements.

Practice Problem

How much N_2 is required to fill a small room with a volume of 27,000 L to 745 mmHg at 25°C?

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

- **Given:** $V = 27{,}000\ L$
  $T = 25\,°C = 298K$
  $P = 745\ mmHg = 0.98\ atm$
  $R = 0.082\ ^{(L)(atm)}/_{(K)(mol)}$
- **Unknown:** $n = ?;\ g = ?$

$$n = \frac{(0.98\ \cancel{atm})(2.7 \times 10^4\ \cancel{L})}{(0.0821\ ^{\cancel{(L)}\cancel{(atm)}}/_{\cancel{(K)}(mol)})(298\cancel{K})} = 1082\ mol\ N_2$$

In grams? $m = (1082\ \cancel{mol})(^{28\ g}/_{1\ \cancel{mol}}) = 30{,}296\ g$