The Gaseous State of Matter

Chapter 12

Properties of Gases

- Gases have an indefinite shape
- Gases expand to fill their containers uniformly
- Gases are compressible
- Gases have low densities
  - air 0.0013 g/mL
  - water 1.00 g/mL
  - iron 7.9 g/mL
- Gases diffuse uniformly throughout their containers to form homogeneous mixtures.
- A gas exerts a pressure

Common units of pressure

101.325 kPa

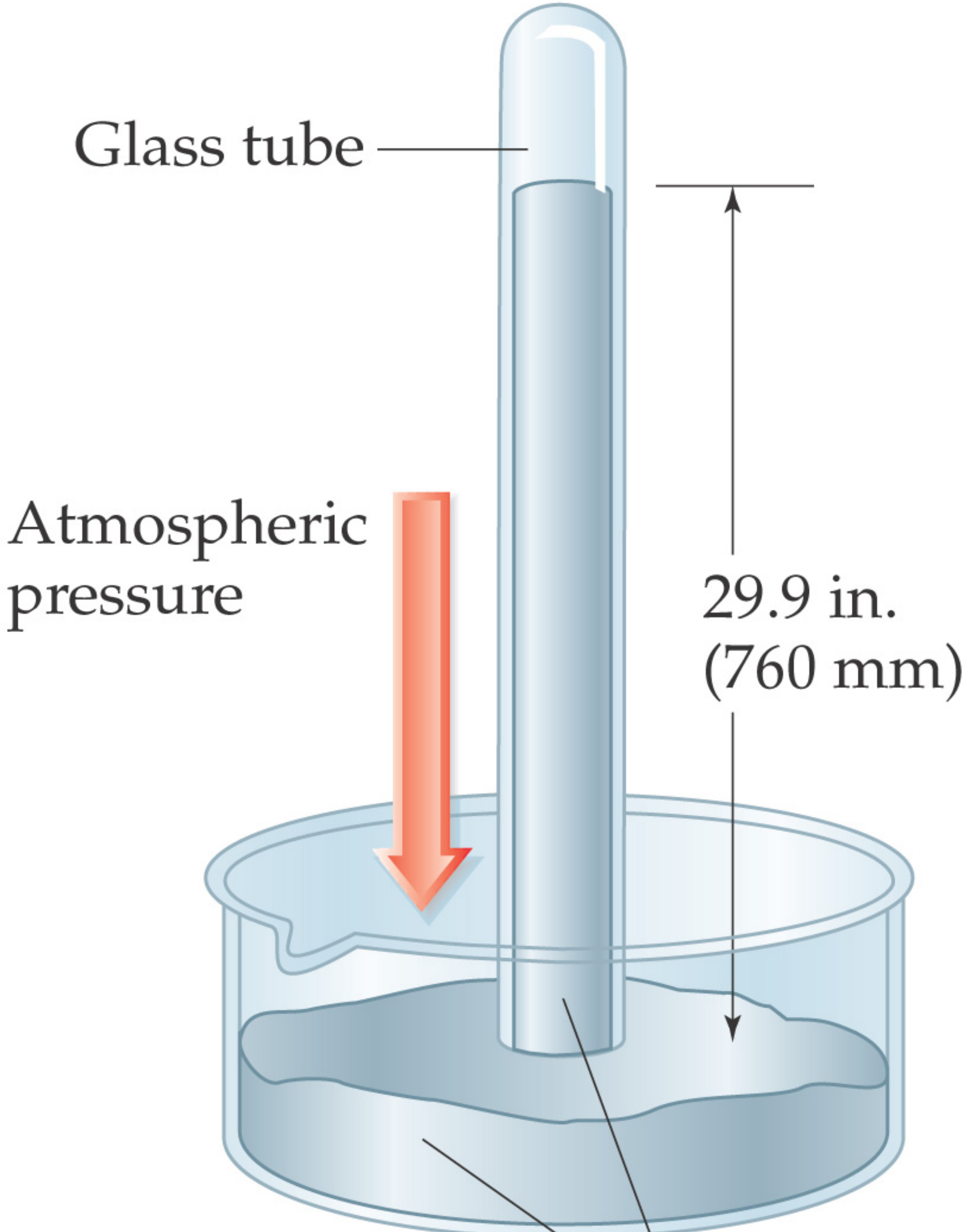
= 760 mm Hg

= 760 torr

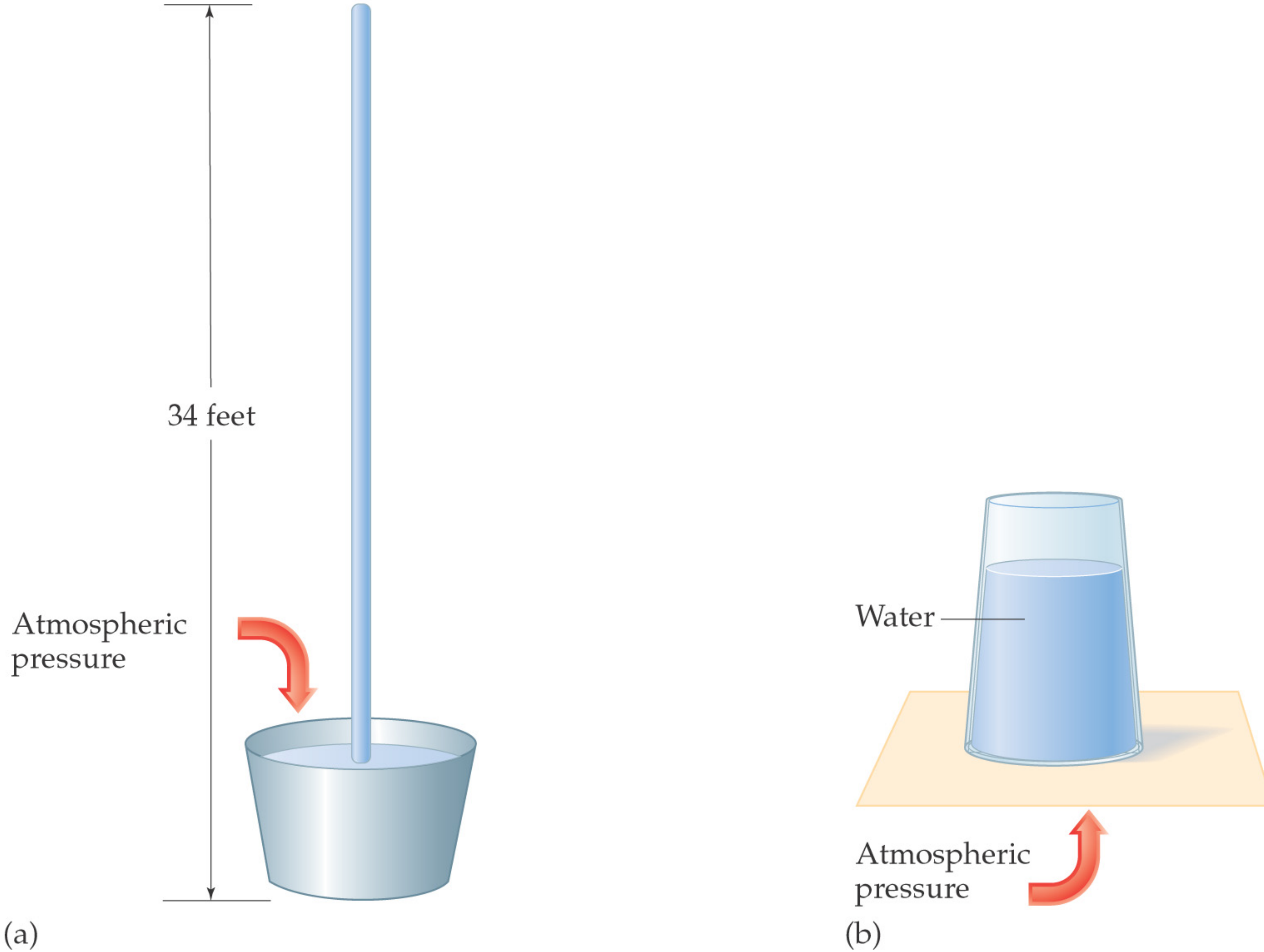
= 1 atm

= 30 in Hg

= 14.7psi


Glass tube
Atmospheric pressure
29.9 in.
(760 mm)
Mercury


Atmospheric
pressure
Molecules in air


34 feet
Atmospheric pressure
(a)
Water
Atmospheric pressure
(b)

- The atmospheric pressure at the summit of Mt. McKinley (Denali) is 606 mm Hg on a certain day. What is the pressure in atmospheres?

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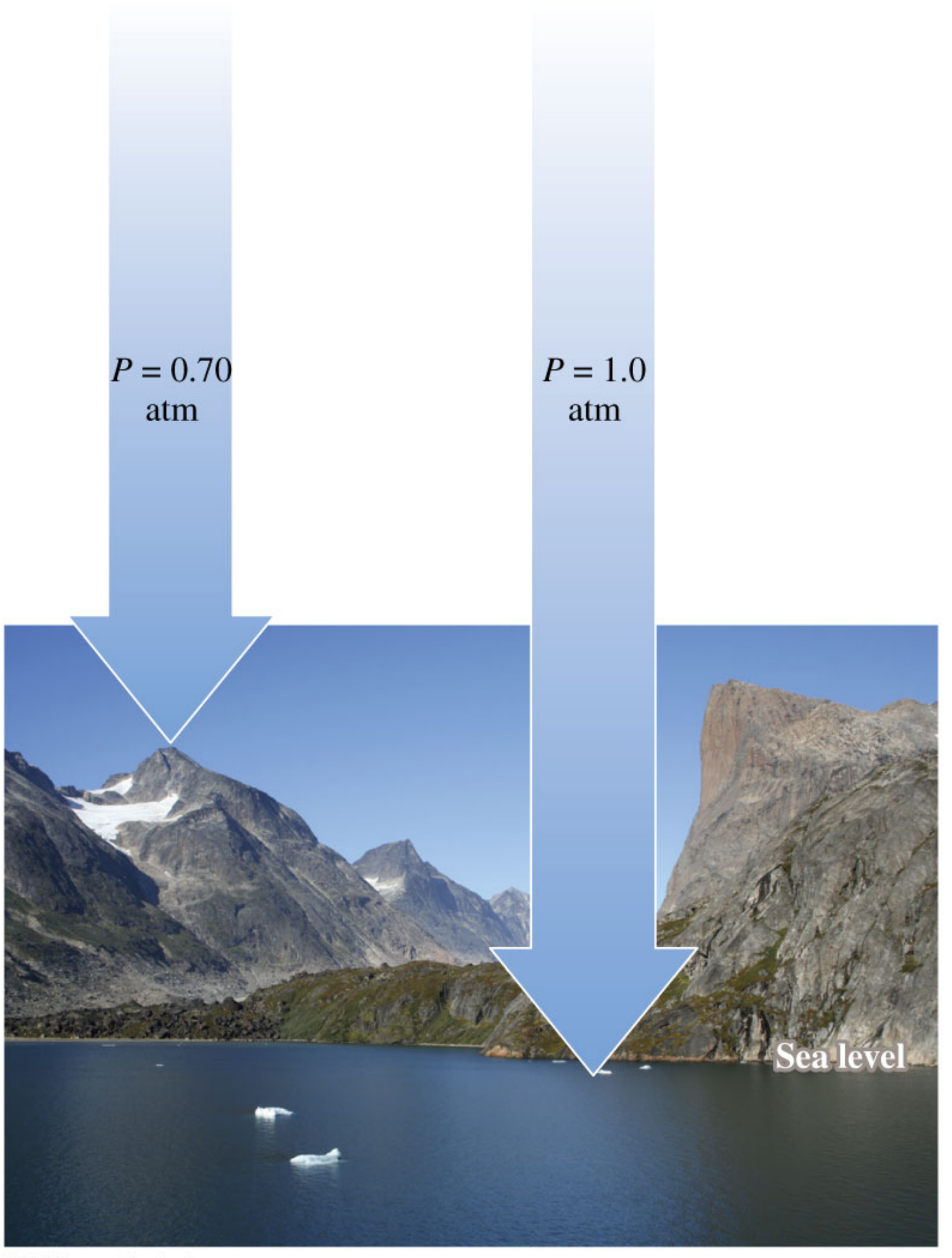
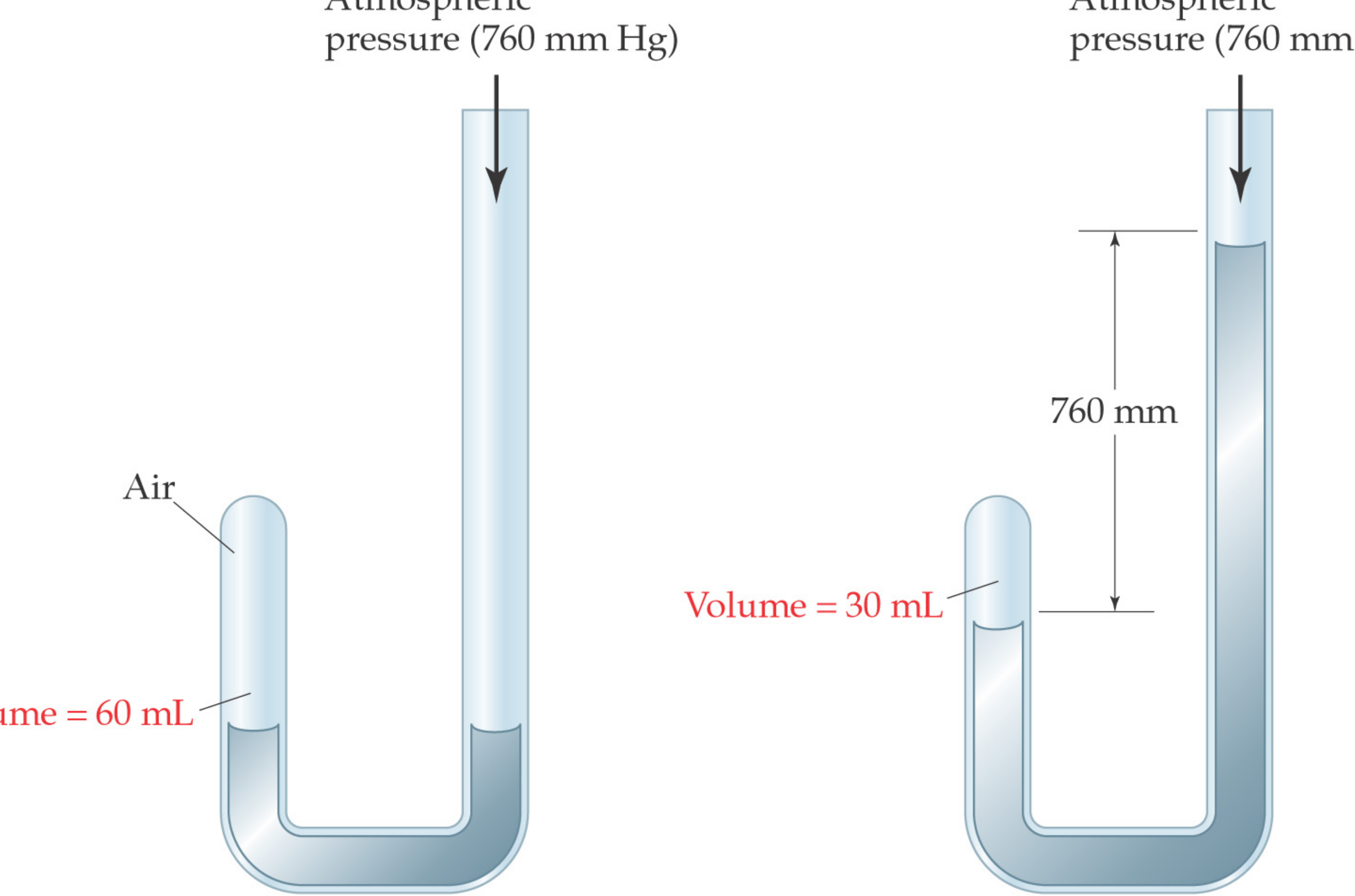


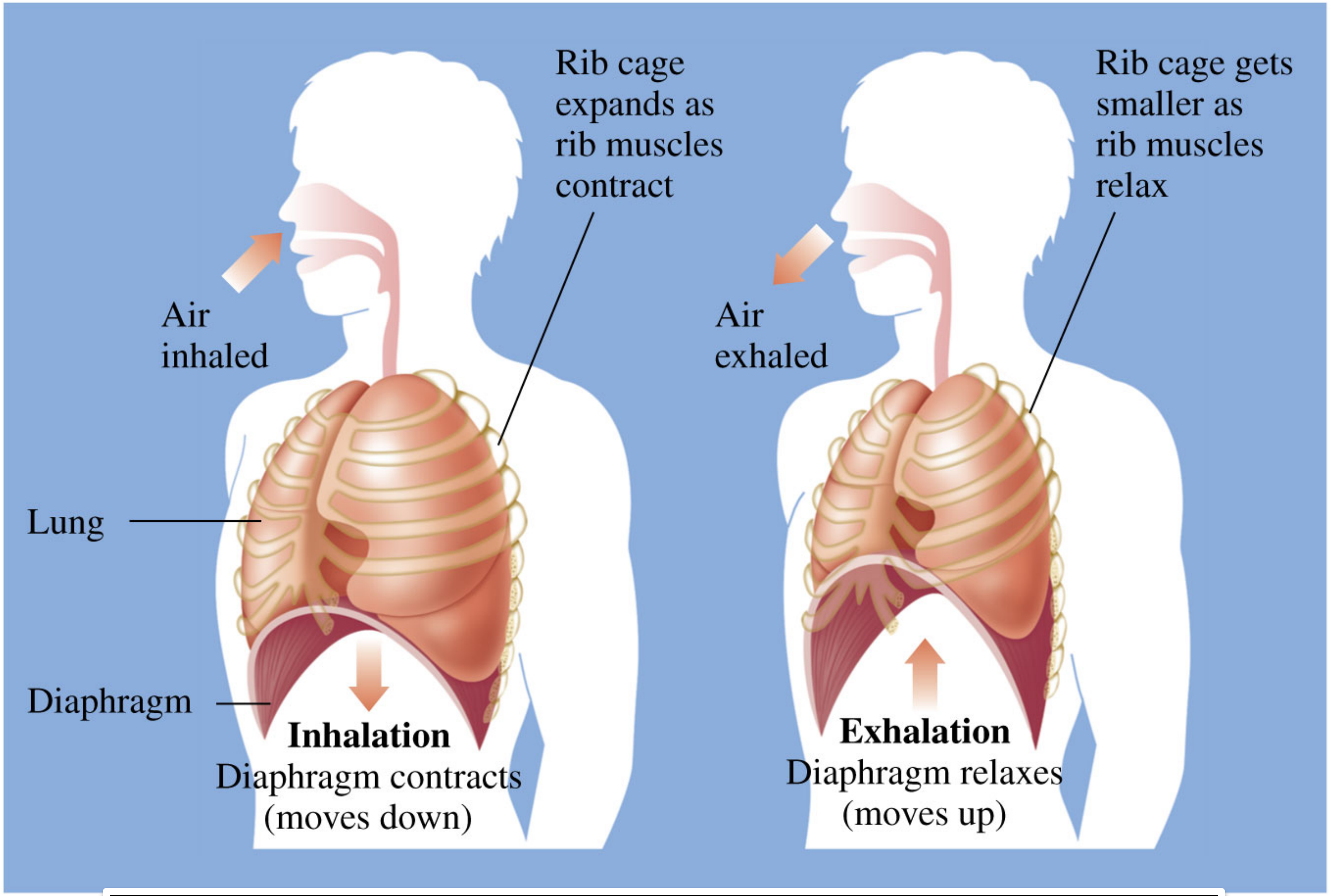


Atmospheric
pressure (760 mm Hg)
Air
ume = 60 mL
Atmospheric
pressure (760 mm
760 mm
Volume = 30 mL

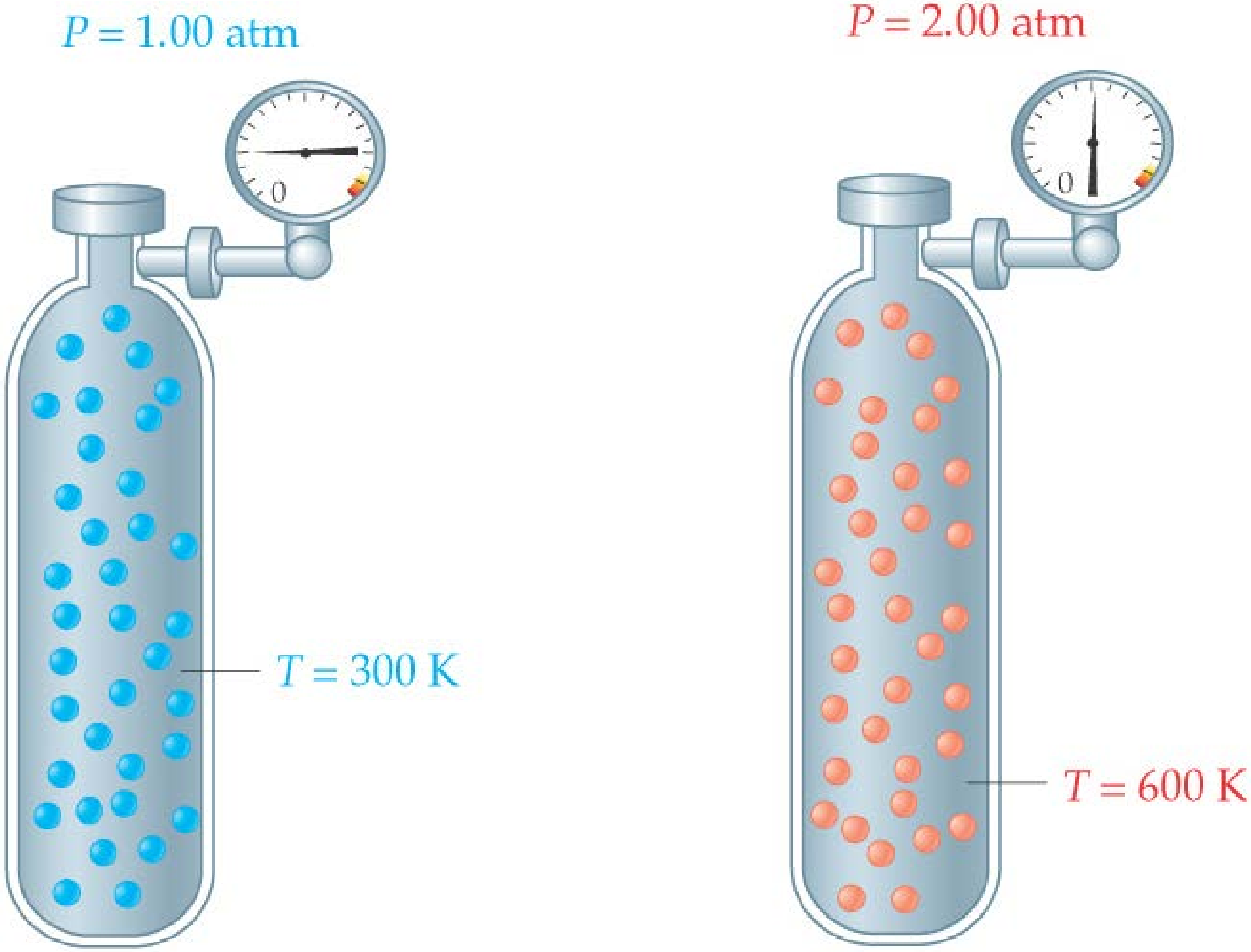
(b)

(b)

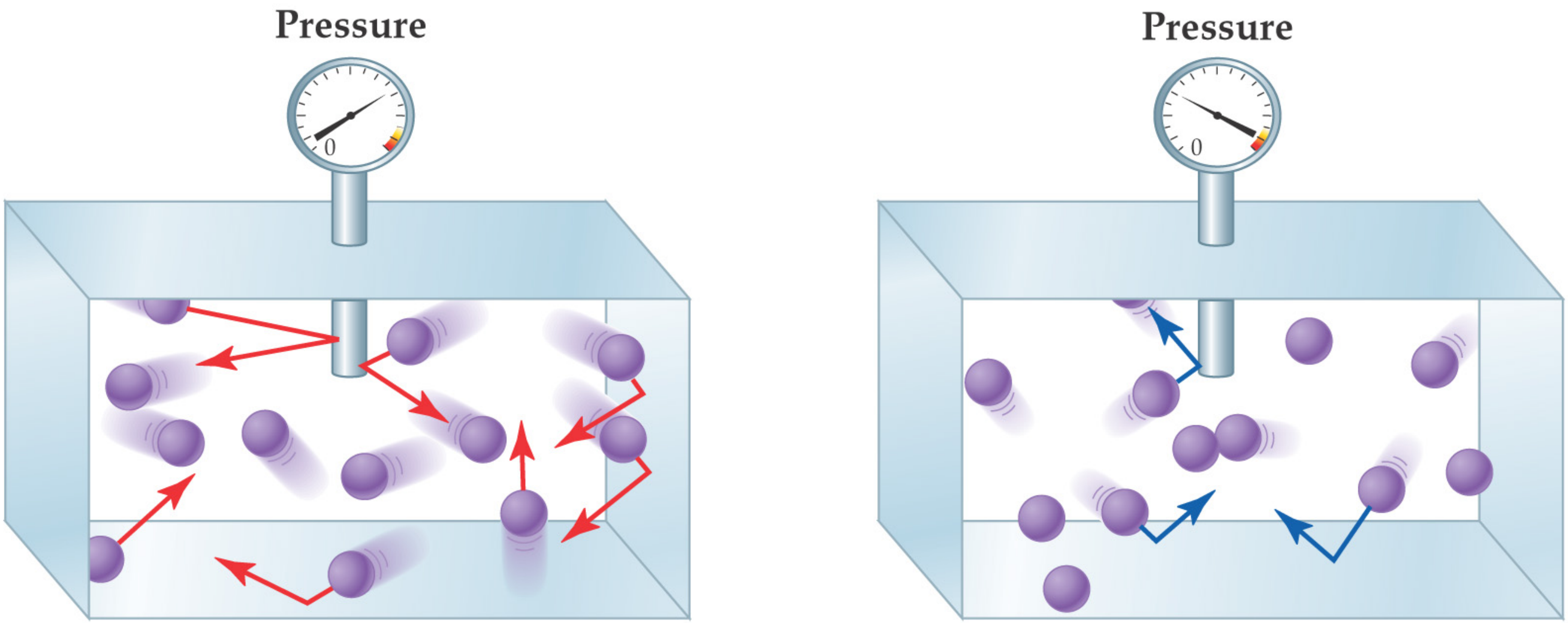
Avogadro's Law



Volume is proportional to moles

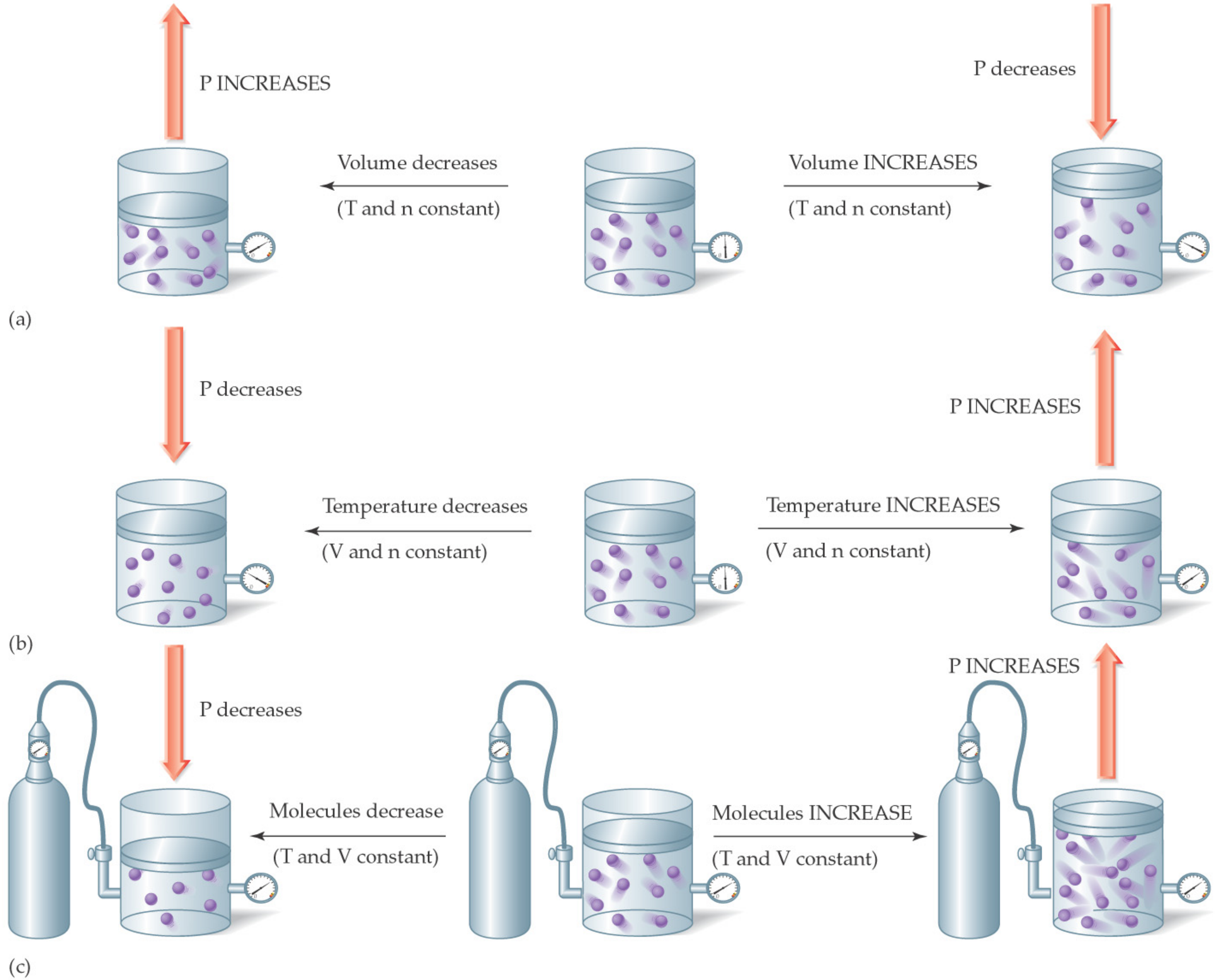


P = 1.00 atm
0
T = 300 K
P = 2.00 atm
0
T = 600 K



(a) Higher pressure
Higher temperature

(b) Lower pressure
Lower temperature



P INCREASES
Volume decreases
(T and n constant)
Volume INCREASES
(T and n constant)
P decreases
(a)
P decreases
P INCREASES
Temperature decreases
(V and n constant)
Temperature INCREASES
(V and n constant)
(b)
P decreases
P INCREASES
Molecules decrease
(T and V constant)
Molecules INCREASE
(T and V constant)
(c)

The Gas Laws

- Boyles Law pressure ⇑ -- volume ⇓
  - $P \propto 1/V$
- Charles Law temperature ⇑ -- volume ⇑
  - $V \propto T$
- Avogadros Law moles ⇑ -- volume ⇑
  - $V \propto n$
- Gay Lussac Law temperature ⇑ -- pressure ⇑
  - $P \propto T$

Ideal Gas Law

$PV = nRT$

- P = pressure (typical units are atm or torr or mm Hg)
- V = volume (typical units are L)
- n = number of moles
- T = temperature (must be in K)
- R = gas constant = 0.0821 L atm/mol K
- = 62.4 L torr/mol K

- An inflated balloon has a volume of 0.55 L at sea level (1.0 atm) and is allowed to rise to a height of 6.4 km, where the pressure is about 0.40 atm. Assuming that the temperature remains constant, what is the final volume of the balloon?

- A container of 452 mL of argon is heated from 22^{o}C to 187^{o}C at constant pressure. What is its final volume?

- A bicycle tire has a pressure of 2000. torr in Death Valley when the temperature is 38^{o}C. What would the pressure be if you took the bike to Lake Tahoe where the temperature was 0^{o}C?

- A small bubble rises from the bottom of a lake, where the temperature and pressure are 8^{o}C and 6.4 atm, to the surface, where the temperature and pressure are 25^{o}C and 1.0 atm. Calculate the final volume of the bubble if its initial volume was 21 mL.

- Sulfur hexafluoride (SF_6) is a colorless, odorless, very unreactive gas. Calculate the pressure (in atm) exerted by 1.82 moles of the gas in a steel vessel of volume 5.43 L at 69.5^{o}C.

- A sample of nitrogen gas kept at 32^{o}C in a 2.3 L container exerts a pressure of 4.7 atm. Calculate the number of moles of gas present.

- Calculate the volume in liters occupied by 7.40 g of CO_2 at 735 torr and 25^oC.

- Helium-filled balloons are used to carry scientific instruments high into the atmosphere. Suppose that a balloon is launched when the temperature is 22.5^{o}C and the barometric pressure is 754 mm Hg. If the balloon's volume is 4.19 x 10^{3} L, what will it be at a height of 20 miles, where the pressure is 70.0 mm Hg and the temperature is –33.0^{o}C?

- Chlorine is widely used to purify municipal water supplies and to treat swimming pool waters. Chlorine is stored in stainless steel cylinders of 30.0 L capacity at a pressure of 160 lb/in^2 at 26^{o}C.

- To what temperature may the cylinder be raised if it is rated to a maximum pressure of 5.35 atm? 14.7 psi = 1 atm

Standard Temperature and Pressure (STP)

- T = 0^oC = 273K, P = 1 atm. = 760 torr
- Calculate the volume of 1.0 mole of a gas at STP.
- What volume will 3.21 moles of Ne occupy at STP?

- A 3/4 full propane tank has a pressure of 3.2 atm at a temperature of 25^{o}C. If you put the tank in the back of your car for a barbecue at the beach and the temperature reaches 103^{o}C, what is the new pressure of the propane in the tank?

- What volume will 4.83 moles of a gas occupy at 35^{o}C and 1.15 atm pressure?

- Find the molar mass of an unknown gas that has a density of 1.45 g/L at 44ºC and 0.331 atm.

- The nitrogen gas in an air bag with a volume of 35 L, exerts a pressure of 850 mm Hg at 25^{o}C. How many grams of N_2 are in the bag?

- Calculate the density of Argon at STP.

Gas Stoichiometry

- $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$
- How many mL of CO_2 can be generated from the reaction of 5.00 g C_3H_8 with excess oxygen at STP?
- How many L of O_2 are required to react with 4.22 L of C_3H_8 at constant Tand P?

Daltons Law of Partial Pressures

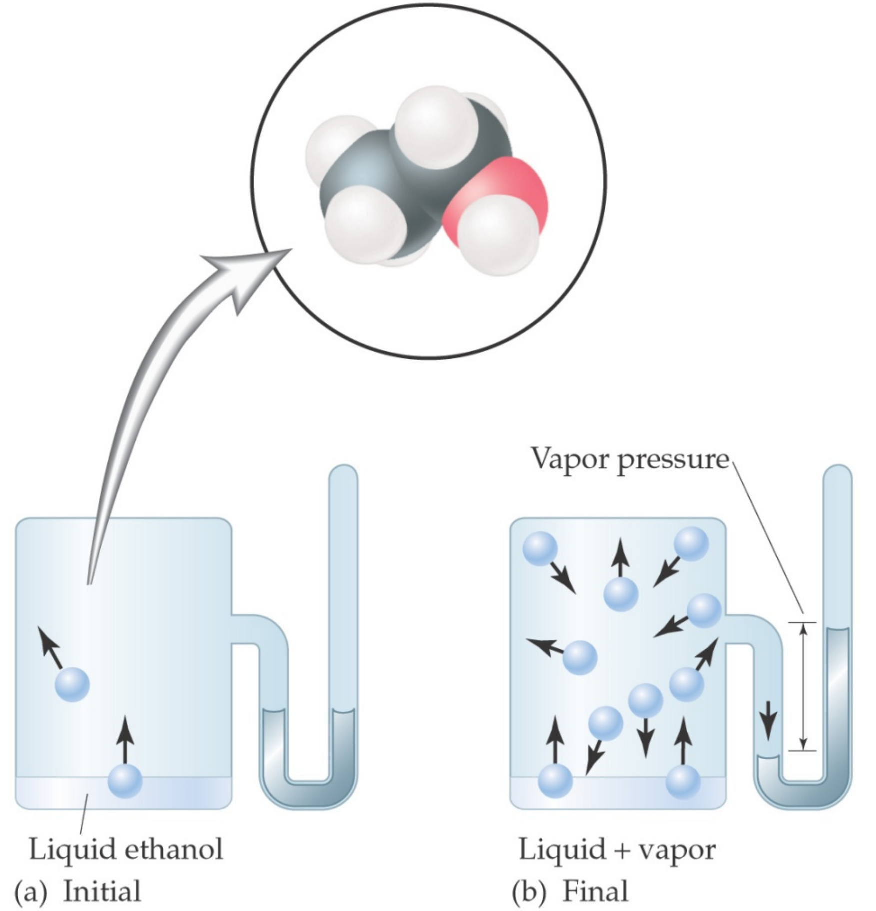
$$P_{total} = P_1 + P_2 + P_3 + \ldots\ldots$$

- the total pressure is equal to the sum of the pressures of the individual gases

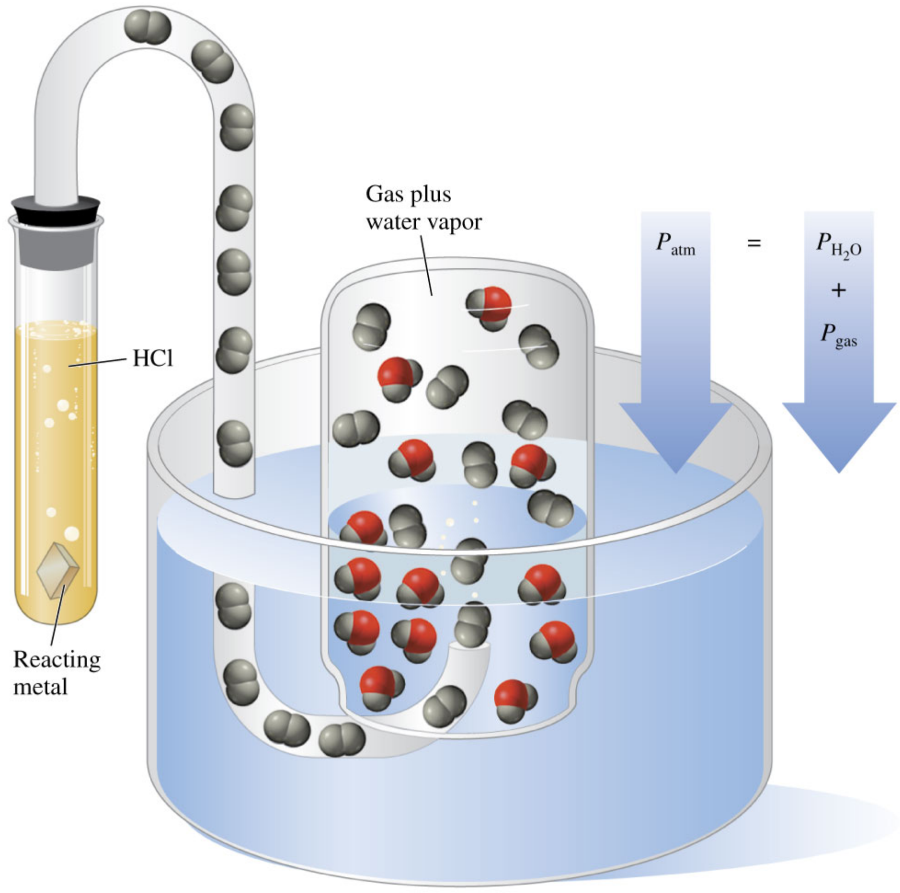
- The atmosphere of Venus contains the following gases.
  - CO_2 392 torr,
  - N_2 834 torr
  - Ar 302 torr
- What is the atmospheric pressure on Venus?

Vapor pressure

- the pressure that is exerted by a vapor that is in equilibrium with its liquid.



Often gases are collected over water and the vapor pressure of the water must be subtracted from the total pressure to find the pressure of the gas collected.



Boiling point

- the temperature at which the vapor pressure is equal to the atmospheric pressure.

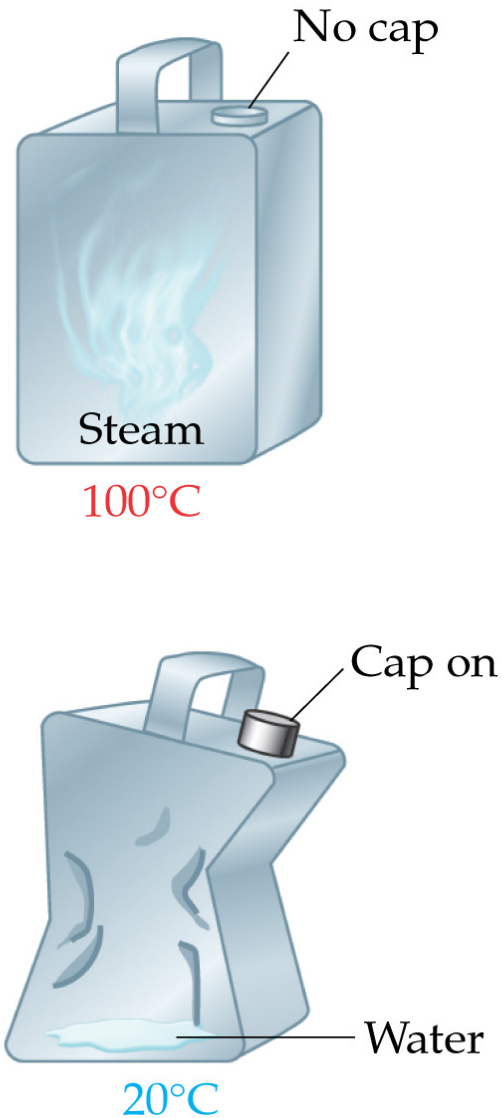
Graham's Law

- Allows us to calculate relative rates of effusion for various gases.
  - Effusion - The escape of a gas through a small hole in its container.
  - Diffusion - The process by which two or more gases begin to mix together.

- Graham's law says that the heavier a particle is (higher MW) the more slowly it will effuse or diffuse under the same conditions.

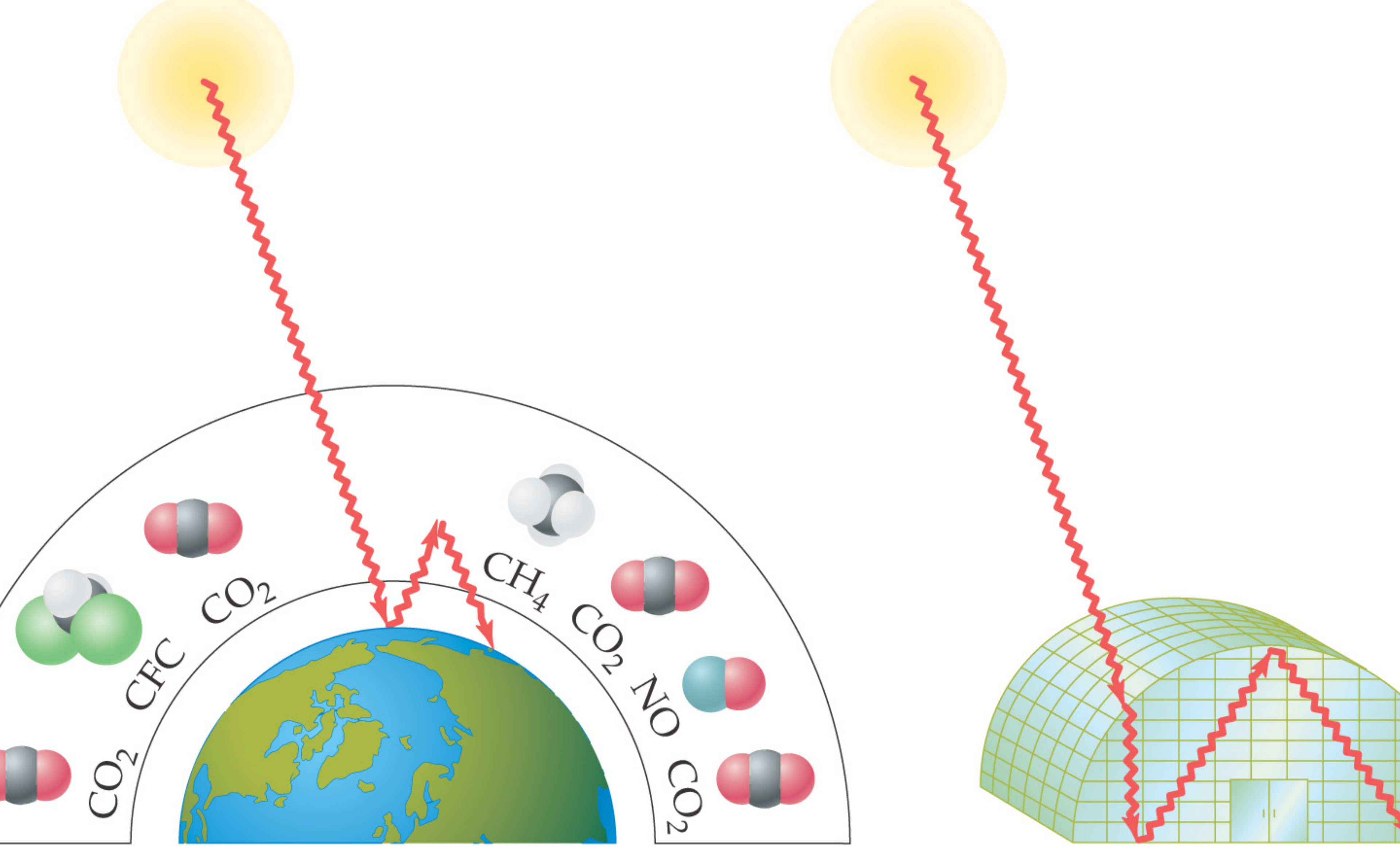
Kinetic Molecular Theory

- Gases consist of molecular particles moving in straight lines at any given instant.
- Gas molecules are widely spaced, the actual volume of molecules is negligible compared to the space they occupy.
- Gas molecules demonstrate rapid motion, move in straight lines and travel in random directions. When they collide with each other they do so with no net loss of energy.
- Gas molecules behave independently -- attractive/repulsive forces between them are negligible.
- The average kinetic energy of the gas particles is proportional to the temperature.



- Key Concepts

- A few drops of water in a metal can are heated to steam and the can is promptly sealed. As the steam cools from 100^{o}C to 20^{o}C, the can is crushed as shown in the diagram. Explain the observation.



(b)