Professor K

gases

Forces between atoms/molecules

- BONDS are the INTRAMOLECULAR FORCES holding the atoms in molecules together...
- What holds the molecules of a solid or liquid together?...
- INTERMOLECULAR FORCES.
  - (more later)
- In an IDEAL GAS, these forces between molecules are nonexistent

Pressure

- The atoms or molecules making up a gas are colliding with each other and their surroundings.
- Gas pressure is expressed in PASCALS which still express FORCE per unit AREA (N/m^2 or kg/ms^2)
- 1 atm =
  760 mm Hg =
  29.921 in Hg =
  760 Torr =
  101.325 kPa =
  1.01325 bar
- Gas pressure is measured with an open- or closed-ended MANOMETER (*not* nanometer)

Example

- A Canadian weather report gives the atmospheric pressure as 100.2 kPa. What is the pressure in Torr? Atm?

- 100.2 kPa (760 Torr/101.325 kPa) = 751.6 Torr
- 751.6 Torr (1 atm/760 Torr) = 0.9889 atm

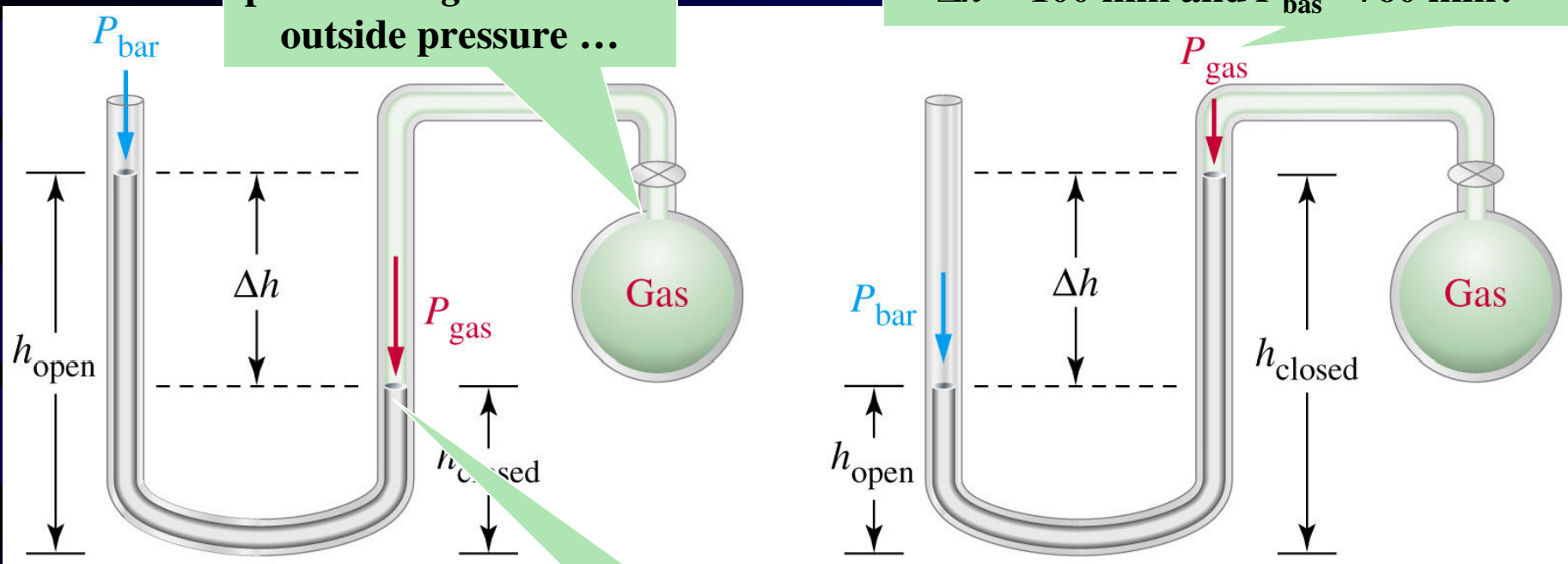
More on pressure

- P = Force/Area (units = N/m^2)
  = gravity•mass/A
  = g•density•volume/A
  = g•d•height•Area/A
  = g•d•h

An open-end manometer

We see that gas pressure is *greater* than outside pressure …

For part (b), what is P_{gas} if Δh = 100 mm and P_{bas}= 760 mm?

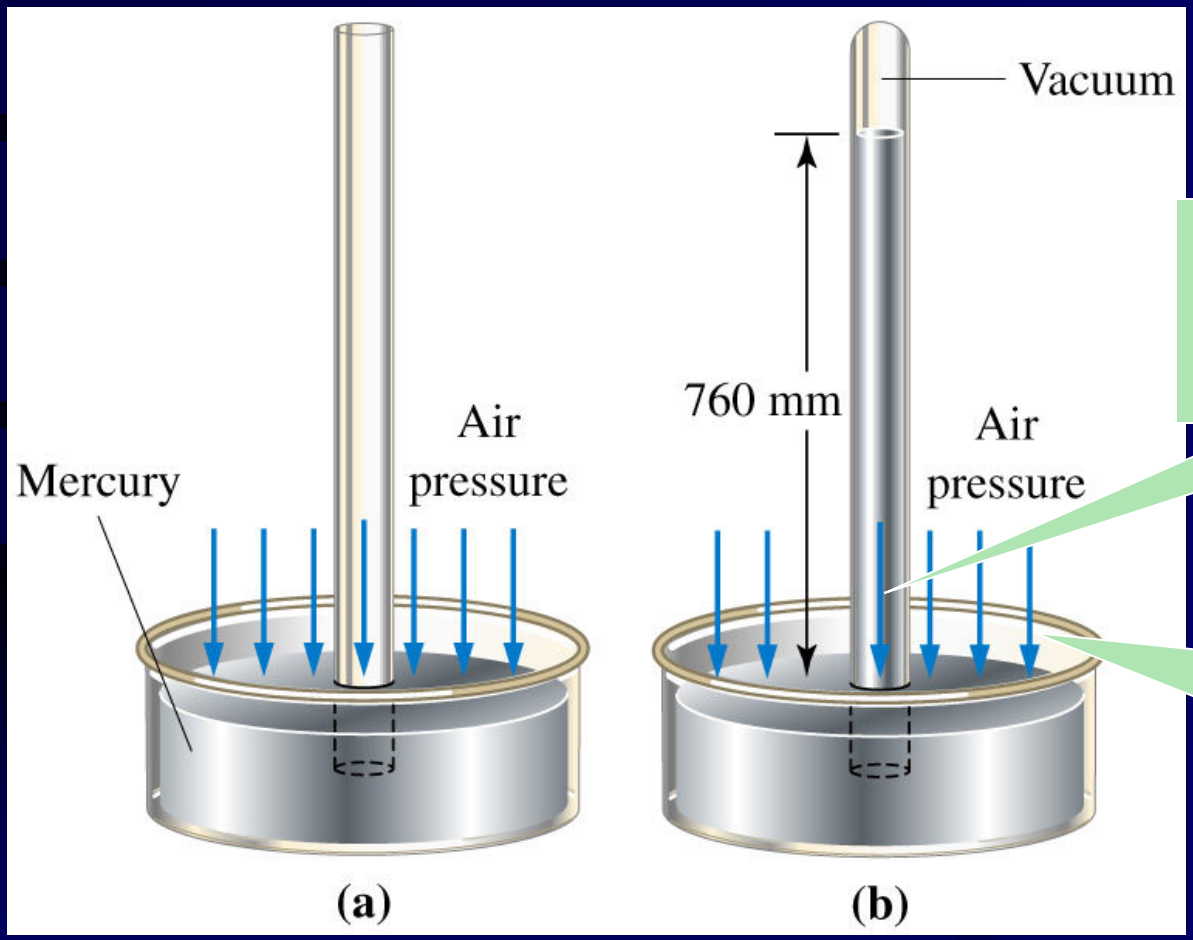


(a) Gas pressure greater than barometric pressure

(b) Gas pressure less than barometric pressure

… because the mercury has been pushed *down* here.

A mercury barometer



The pressure exerted by the column of mercury …

… must be the *same* as that exerted by the atmosphere.

Gas laws

The key equation you must remember is PV=nRT

- Boyle $V \propto \frac{1}{P} \cdots\cdots PV = a \cdots\cdots P_1V_1 = P_3V_2 = a$
- Charles $V \propto T \cdots\cdots V = bT \cdots\cdots \frac{V_1}{T_1} = \frac{V_2}{T_2} = b$
- Avogadro $V \propto n \cdots\cdots V = cn$
- Combined $\frac{PV}{nT} = const$

We can cancel any term (*P*, *V*, *n*, *T*) that is the same on both sides.

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

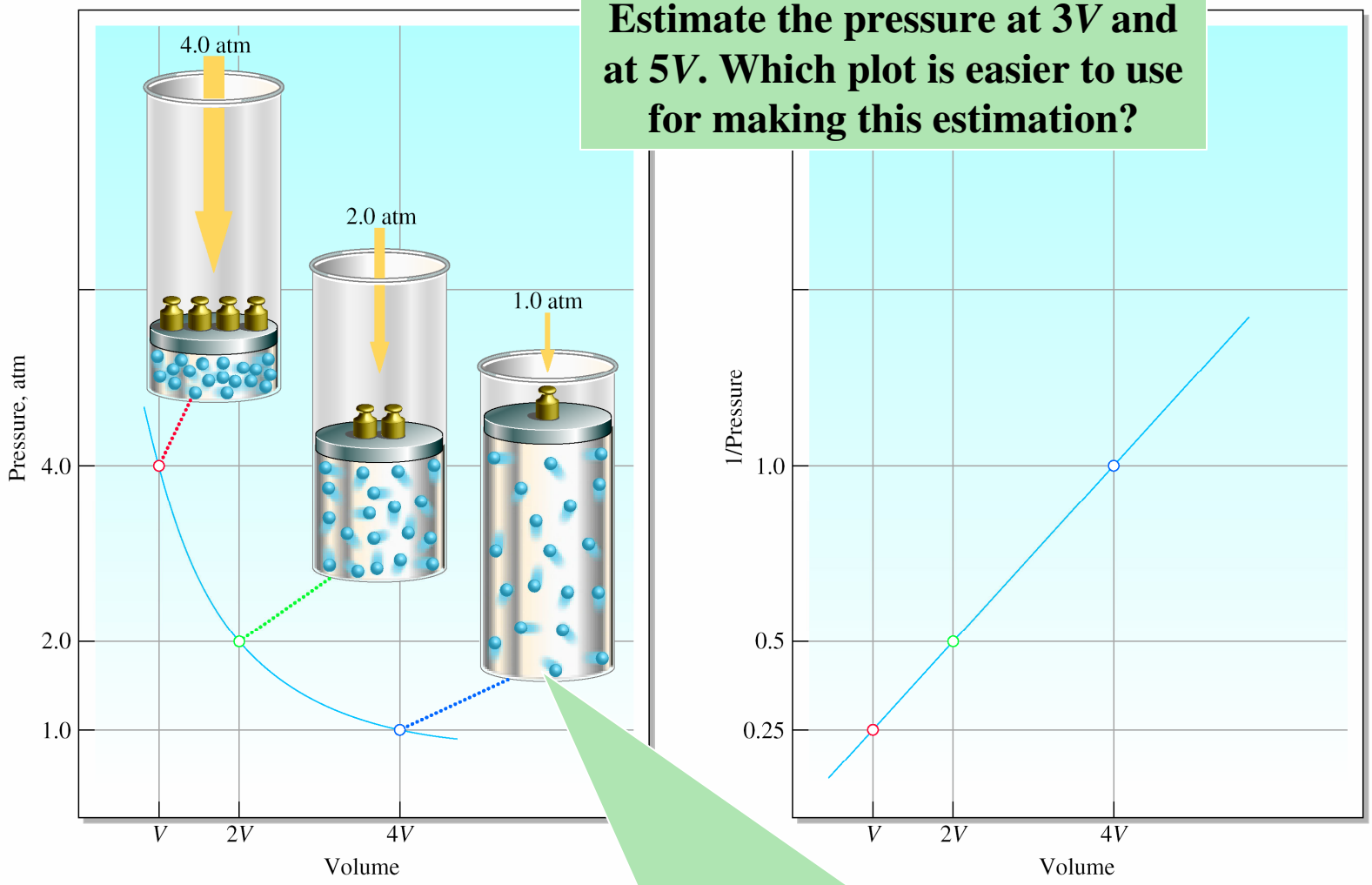
STP

- Standard Temperature and Pressure
- 1 atm
- 0°C (273.15K)

- R is the ideal gas constant
  8.314472 J/mol•K
  0.0820574 L•atm/mol•K

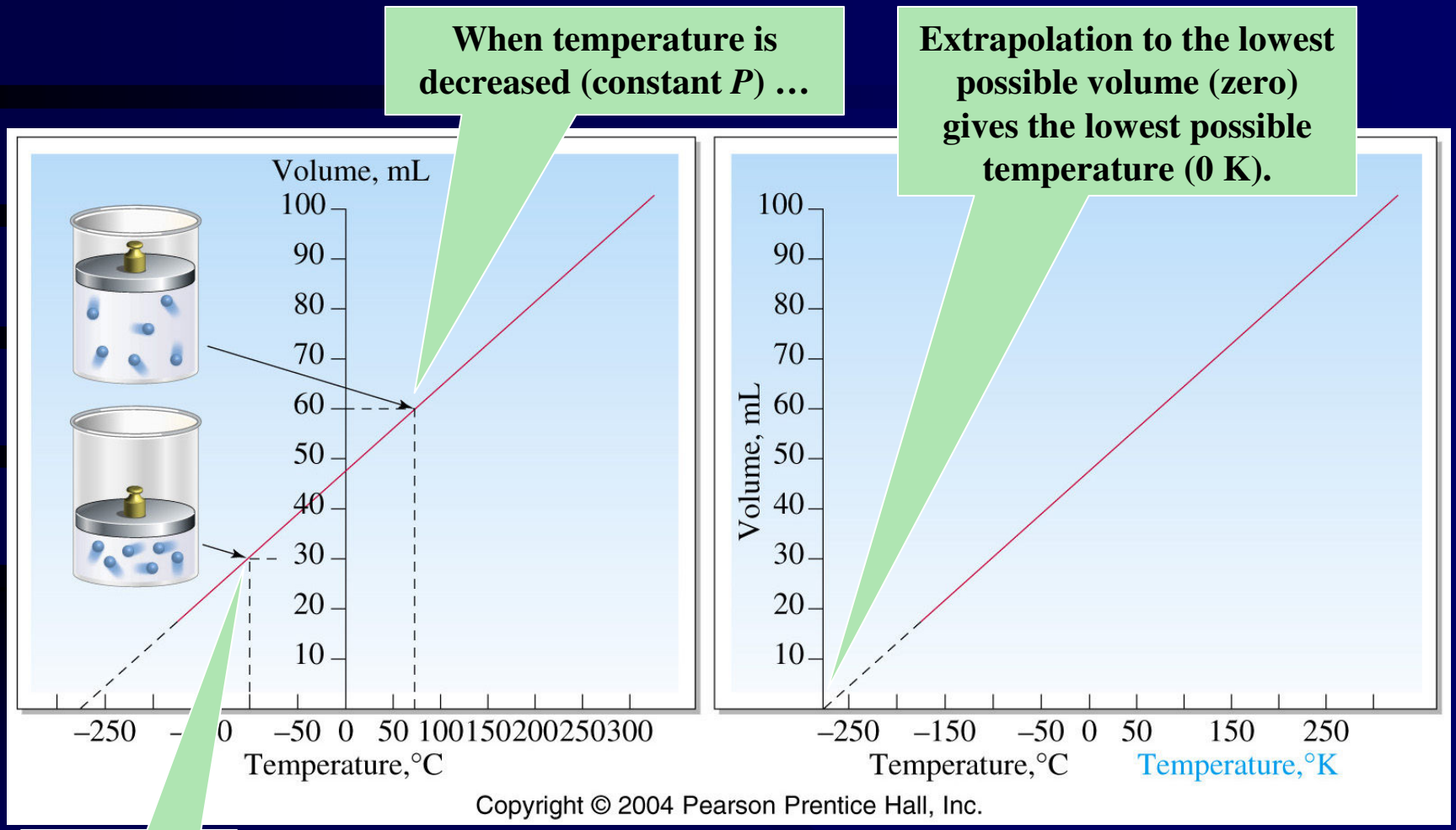
Graphical representation of Boyle's law

Estimate the pressure at 3*V* and at 5*V*. Which plot is easier to use for making this estimation?

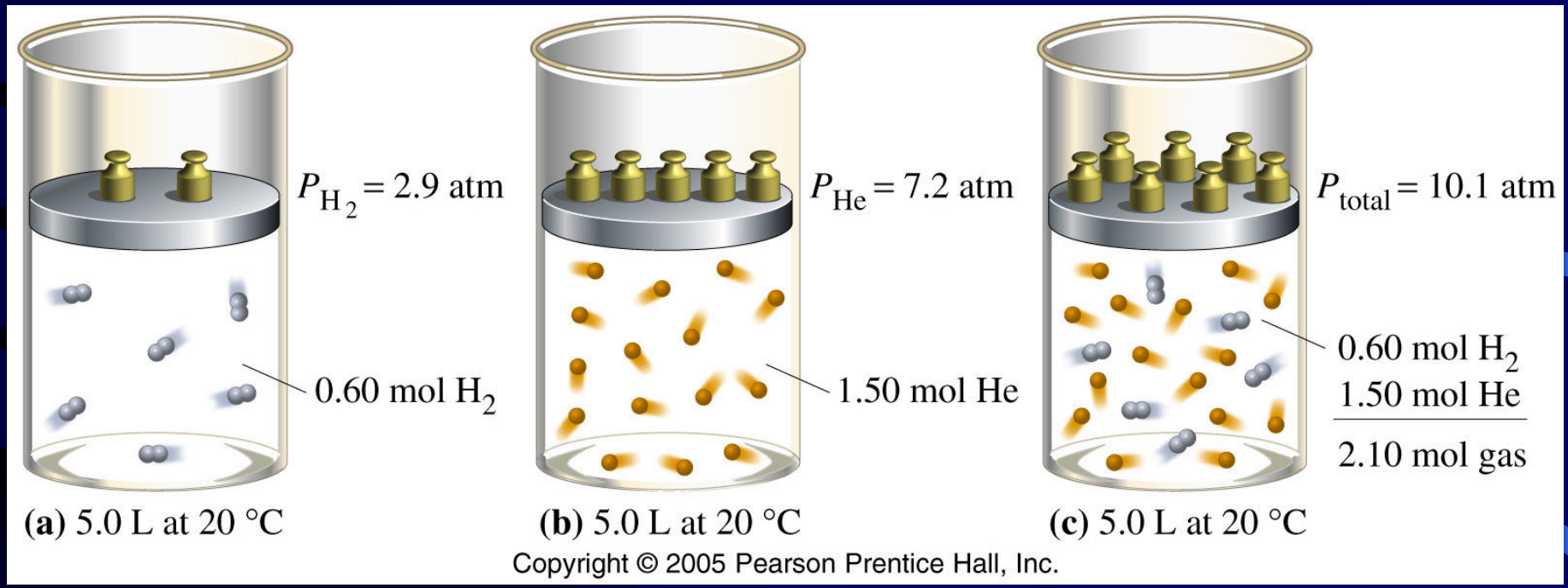


When volume is increased there is more area for the molecules to "hit"; less force *per* area.

Graphical representation of Charles's law



Graphical representation of Avogadro's law



Dalton's law of partial pressures

- The total pressure exerted by a mixture of gases is equal to the sum of the ***partial pressures*** exerted by the separate gases:

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

- **Partial pressure**: the pressure a gas would exert if it were alone in the container.

$$P_1 = \frac{n_1 RT}{V} \qquad P_2 = \frac{n_2 RT}{V} \qquad P_3 = \frac{n_3 RT}{V} \cdots$$

Kinetic-molecular theory

- Gases are particles in random straight-line motion
- Gas particles are point masses
  - (no volume)
- Collisions are perfectly elastic
  - (no attraction)

Assumptions in the ideal law

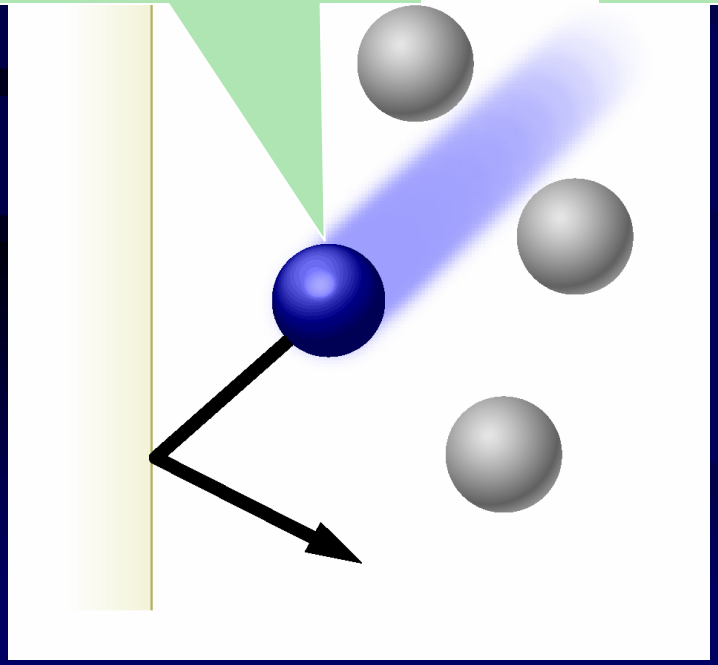
- Particles do not interact
- Particles are “point masses”
  - –they have no size
  - –they occupy no space

REAL gas deviations

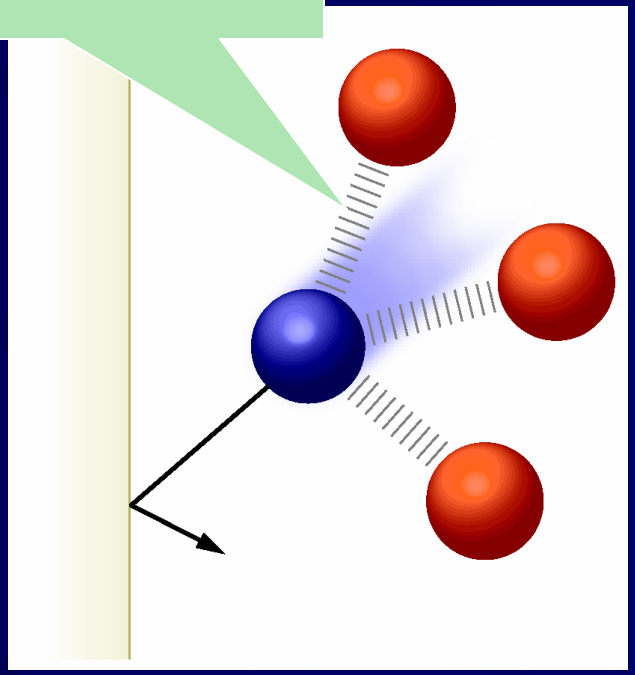
- Particles do have some attraction for each other
  - pressure measured is LESS than ideal
- Particles do occupy space
  - the volume measured is MORE than actual

Intermolecular forces of attraction

Occupying no space and having no attraction for its neighbors, the blue molecule simply moves by the neighboring molecules, and strikes the wall of the container with considerable force.



Forces of attraction exist between the blue molecule and neighboring molecules in a real gas; the blue molecule strikes the wall with less force— measured pressure is lower.



Real gases

- van der Waals equation (real gases):

$$[P + \{(n^2a) / V^2\}](V - nb) = nRT$$

- *a* is related to intermolecular force strength.
- *b* is related to volume of the gas molecules (in liters per mole).
- Both *a* and *b* are *empirical* constants, determined by experiment.

Table 5.5 van der Waals Constants for Selected Gases

Substance	a (L^2 atm mol^{-2})	b (L mol^{-1})
He	0.0341	0.02370
Ar	1.34	0.0322
H_2	0.244	0.0266
O_2	1.36	0.0318
CO_2	3.59	0.0427
CCl_4	20.4	0.1383

Gas kinetics

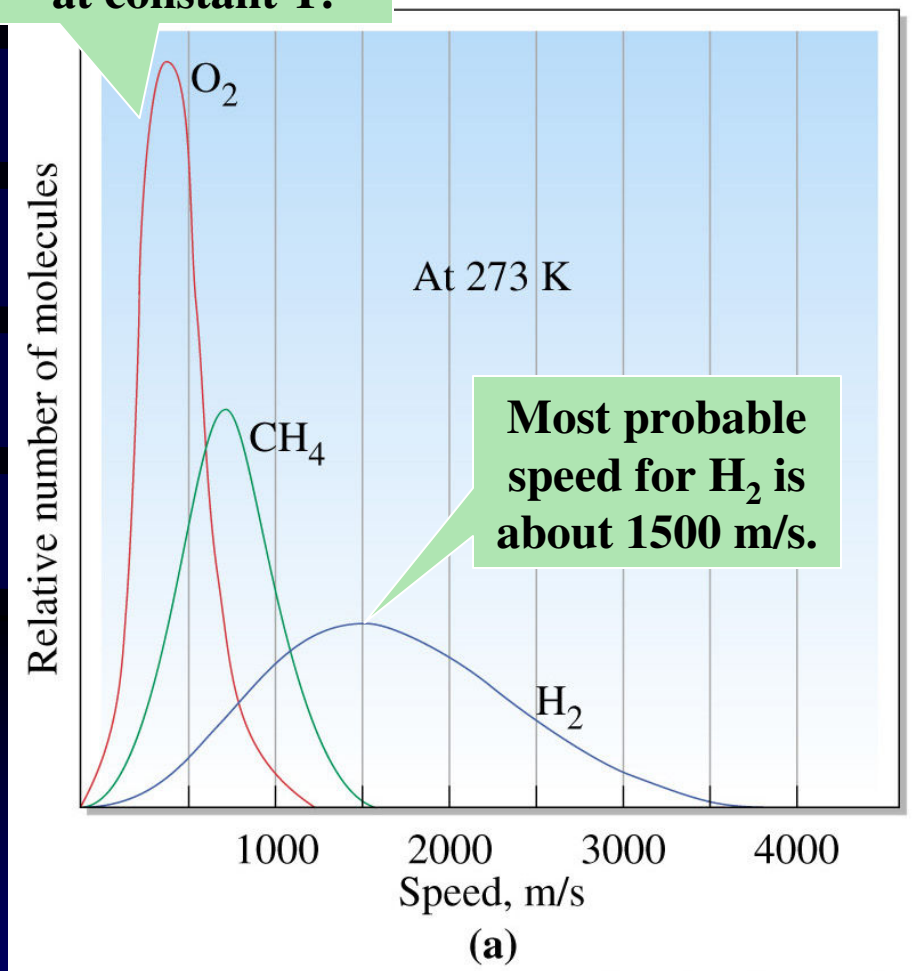
- Gas molecules do not all move at the same speed, they have a wide distribution of speeds.
- The root-mean-square speed, u_{rms}, is the square root of the average of the squares of the molecular speeds.

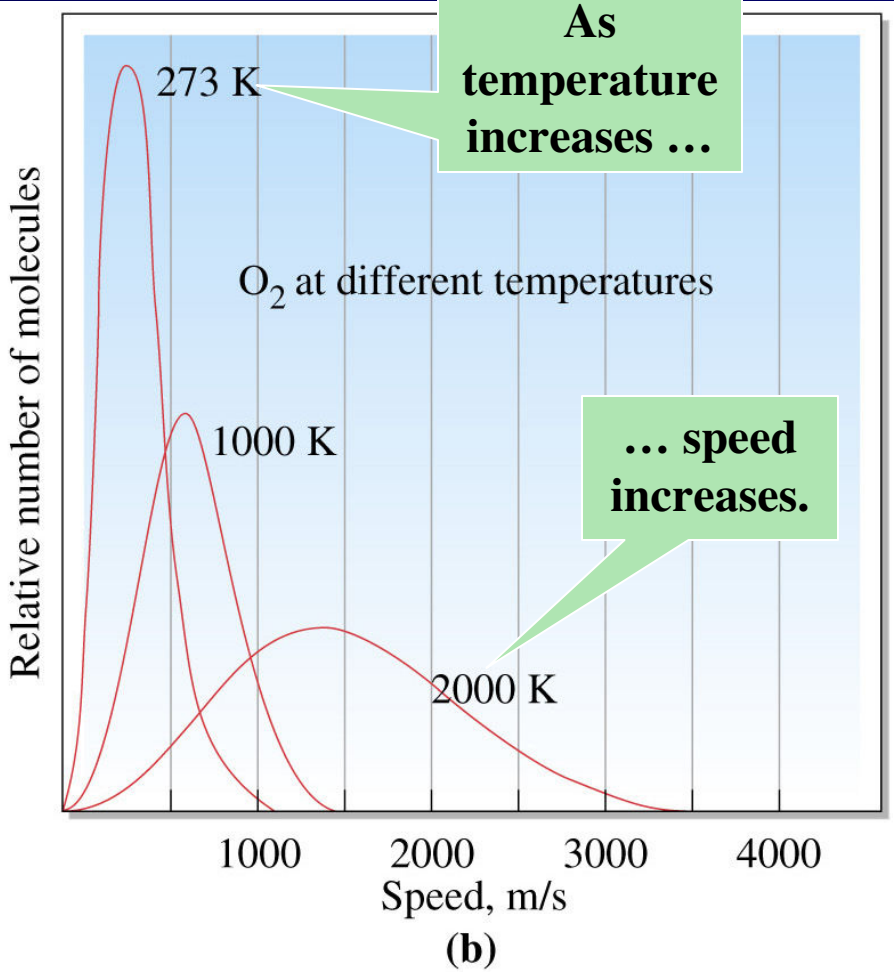
$$u_{rms} = \sqrt{\overline{u^2}} = \sqrt{\frac{3RT}{M}}$$

- Typical speeds are quite high- on the order of 1000 m/s.
- At a fixed temperature, molecules of higher mass (M) move *more slowly* than molecules of lower mass.
- LIGHTER IS FASTER

Molecular speeds

The higher the molar mass, the lower the most-probable speed at constant T.





Diffusion and effusion

- ***Diffusion*** is the process by which one substance mixes with one or more other substances as a result of the translational motion of molecules.
  - Diffusion of gases is much slower than would be predicted by molecular speeds due to the frequent collisions of molecules.
  - The average distance a molecule travels between collisions is called its *mean free path*.
- ***Effusion*** is the process in which a gas escapes from its container through a tiny hole, or orifice.
  - Effusion is (mathematically) simpler than diffusion since effusion does not involve molecular collisions.
  - At a fixed *T*, the rates of effusion of gas molecules are *inversely* proportional to the square roots of their molar masses:

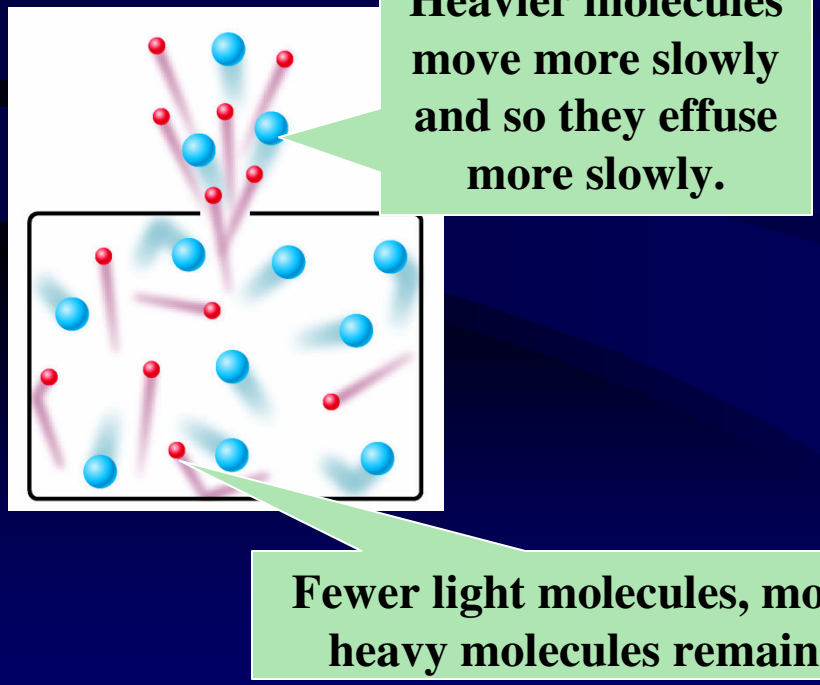
Diffusion of gases

Why is the "smoke" closer to the HCl bottle than the NH_3 bottle?

Lighter ammonia molecules move faster, and diffuse faster, than heavier HCl molecules.

Effusion

- ***Effusion*** is the process in which a gas escapes from its container through a tiny hole, or orifice.



- Effusion is (mathematically) simpler than diffusion since effusion does not involve molecular collisions.
- At a fixed T, the rates of effusion of gas molecules are inversely proportional to the square roots of their molar masses:

$$\frac{\text{rate}_1}{\text{rate}_2} = \frac{\sqrt{\frac{3RT}{M_1}}}{\sqrt{\frac{3RT}{M_2}}} = \sqrt{\frac{M_2}{M_1}}$$

QUIZ

- Express the product of 5.97 and 6.918 using the appropriate number of significant figures.
- A) 41.3
- B) 41.30
- C) 41.300460
- D) 41
- E) 12.9
- Answer: A

QUIZ

- Convert 7.62 quarts to liters. (3.785 L = 1 gal; 4 qts = 1 gal)
- A) 115
- B) 8.05
- C) 28.8
- D) 7.21
- E) 30.5
- Answer: 7.21

QUIZ

- A solid block of material has the dimensions 1.2 cm x 3.5 cm x 4.2 cm. If the mass of the block is exactly 50 g, what is the density of the material?
- A) 880
- B) 0.35
- C) 2.8
- D) 28
- E) 0.28
- Answer: 2.8

QUIZ

- What is the length in meters of an 4.0×10^1 inch rod? (1 m = 39.37in)
- A) 2.3
- B) 1600
- C) 120
- D) 1.0
- E) 1.3
- Answer: 1.0

QUIZ

- How many neutrons are there in the nucleus of a ^{232}Th atom?
- A) 232
- B) 90
- C) 81
- D) 151
- E) 142
- Answer: 142

QUIZ

- An $^{56}Fe^{2+}$ particle contains
- A) 28 protons, 28 neutrons and 26 electrons.
- B) 26 protons, 30 neutrons and 24 electrons.
- C) 26 protons, 26 neutrons and 26 electrons.
- D) 58 protons, 58 neutrons and 56 electrons.
- E) 54 protons, 56 neutrons and 52 electrons.
- Answer: B

QUIZ

- Which formula could not be that of an alkane?
- A) CH_4
- B) C_3H_8
- C) C_6H_{10}
- D) C_8H_{18}
- E) $C_{10}H_{22}$
- Answer: C

QUIZ

- Which formula could NOT be that of a cycloalkane?
- A) C_3H_6
- B) C_5H_{10}
- C) C_7H_{14}
- D) C_8H_{16}
- E) $C_{10}H_{22}$
- Answer: E

QUIZ

- Name the straight chain hydrocarbons shown below in the order given:
- C_4H_{10}, C_5H_{12}, C_3H_8
- A) propane, pentane, butane
- B) propane, hexane, ethane
- C) butane, pentane, propane
- D) propane, butane, ethane
- E) butane, pentane, ethane
- Answer: C

QUIZ

- Calculate to five significant figures, the formula mass of the compound $(NH_4)_2SO_4$
- A) 132.14
- B) 114.10
- C) 132.00
- D) 114.11
- E) 66.138
- Answer: A

QUIZ

- Calculate the number of moles of $Ba(OH)_2$ present in a 100.0 g sample.
- A) 0.137
- B) 0.171
- C) 0.584
- D) 0.648
- E) 100.
- Answer: C

QUIZ

- How many F– ions are present in 2.50 moles of BF_2?
- A) 5.00
- B) 3.01×10^{24}
- C) 1.51×10^{24}
- D) 2.50
- E) 6.02×10^{24}
- Answer: B

QUIZ

- In the compound Na_2HPO_4 which element is present in the largest percent by mass?
- A) Na
- B) H
- C) P
- D) O
- E) H and P
- Answer: D

QUIZ

- Which of the following cannot be an empirical formula?
- A) C_2H_2
- B) CH_2
- C) CH_3
- D) C_2H
- E) C_2H_3
- Answer: A

QUIZ

- When the following equation is balanced with lowest ratio whole number coefficients, the coefficient of CO_2 is

  $C_4H_{10}\ (g) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (l)$

- A) 4
- B) 5
- C) 6
- D) 7
- E) 8
- Answer: E

QUIZ

- Benzene and bromine react to form bromobenzene, as represented by the equation below. The densities of benzene and bromobenzene are 0.879 g/mL and 1.50 g/mL, respectively. How many mL of bromobenzene can be prepared from 12.5 mL benzene?

$$C_6H_6\ (l) + Br_2\ (l) \rightarrow C_6H_5Br\ (l) + HBr$$

- A) 21.3
- B) 37.7
- C) 3.64
- D) 25.1
- E) 14.7
- Answer: E

QUIZ

- What would be the molarity of a solution obtained by diluting 125 mL of 6.00 M HCl to 500. mL?
- A) 1.25
- B) 1.50
- C) 0.667
- D) 24.0
- E) 10.4
- Answer: B

QUIZ

- A beaker containing 250 mL of a 0.500 M solution of acetic acid (CH_3COOH) is added to 125 mL of a 0.850 M solution of sodium carbonate. The reaction that ensues produces carbon dioxide, sodium acetate (CH_3COONa), and water. How many grams of carbon dioxide are produced?
- A) 0.00241
- B) 2.75
- C) 15.4
- D) 4.67
- E) 5.50
- Answer: B

QUIZ

- Consider 0.1 M solutions of the following substances. Which would have the greatest electrical conductivity?
- A) CH_3NH_2
- B) CH_3COOH
- C) HCl
- D) $Ca(OH)_2$
- E) NH_4Br
- Answer: D

QUIZ

- Which of the following species is not a base in water?
- A) NaOH
- B) CH_3NH_2
- C) CH_3OH
- D) NH_3
- E) All of the above are bases in water.
- Answer: C

QUIZ

- Calculate the volume, in milliliters, of 0.600 M HCl required to titrate 25.0 mL 0.350 M KOH.
- A) 0.938
- B) 5.25
- C) 15.6
- D) 14.6
- E) 42.9
- Answer: D

QUIZ

- What is the oxidation number of chromium in $Cr_2O_7^{2-}$?
- A) +2
- B) +3
- C) +4
- D) +6
- E) –3
- Answer: D

QUIZ

- An oxidizing agent
- A) loses electrons.
- B) must contain oxygen.
- C) increases its oxidation number.
- D) becomes oxidized.
- E) none of these
- Answer: E

QUIZ

- Regarding the following reaction, what statement is incorrect?

  $Mg + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu$

- A) Mg is oxidized.
- B) Cu^{2+} is the oxidizing agent.
- C) Mg^{2+} could be an oxidizing agent.
- D) Mg is the reducing agent.
- E) Cu^{2+} is oxidized.
- Answer: E

QUIZ

- In the reaction
  $Cl_2\ (aq) + 2\ I^-\ (aq) \rightarrow 2\ Cl^-\ (aq) + I_2\ (aq)$
  the oxidizing agent is
- A) Cl_2
- B) I^-
- C) Cl^-
- D) I_2
- E) H_2O
- Answer: A

QUIZ

- Which of the following is a strong electrolyte?
- A) HCl
- B) H_2O
- C) HCOOH
- D) CH_3COOH
- E) C_6H_6
- Answer: A