CHEM Ch. 11 NOTES ~ BEHAVIOR OF GASES

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics.*

Sec. 11.1 Changing gas dimensions

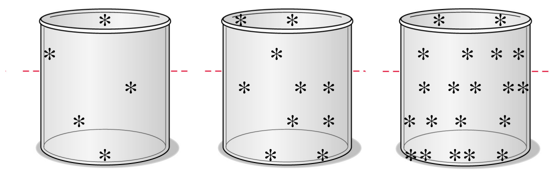
Remember from last chapter...

STANDARD ATMOSPHERIC PRESSURE:
1 atm = 760. mm Hg = 760. torr = 101.3 kPa = 14.7 psi

I. Adding or removing a gas

A. *adding gas*
   1) *increases number of particles*
   2) *increases the pressure (number of collisions)*

B. *removing gas*
   1) *decreases the number of particles*
   2) *decreases the pressure (number of collisions)*

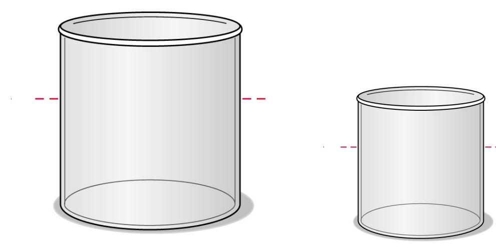


5 particles 0.5 atm | 10 particles 1 atm | 20 particles 2 atm

II. Changing container size

A. *increase container size*
   1) *increases the volume*
   2) *decreases the pressure*
   3) gases cool

B. *decrease container size*
   1) *decreases the volume*
   2) *increases the pressure*
   3) gases heat up

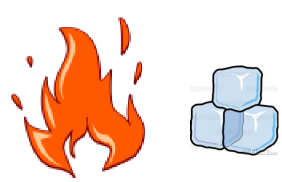


A. B.

III. Heating or cooling a gas

A. *increase temp.:*
   increases the kinetic energy (K.E.) and pressure

B. *decrease temp.*
   decreases the K.E. and pressure



NOTE: for the gas laws… ***1*** *= initial* ***2*** *= final*
P *= pressure* ***V*** *= volume* ***T*** *= temperature* ***n*** *= # of moles* ***R*** *= a constant*

Sec. 11.2 Gas Laws

IV. Boyle's Law

A. **BOYLE'S LAW**: for a gas a constant temperature, pressure and volume are indirectly or inversely proportional. P α 1/V

B. equation: $\boxed{P_1V_1 = P_2V_2}$

C. examples

E1) A sample of CO gas is at 0.66 atm in a 3.0 L piston container. If the pressure is increased to 5.0 atm, what is the new volume? Temperature is constant.

$P_1 = 0.66$ atm $P_2 = 5.0$ atm $P_1V_1 = P_2\boxed{V_2}$ $\dfrac{P_1V_1}{P_2} = V_2$ $\dfrac{(0.66\ \text{atm})(3.0\ \text{L})}{(5.0\ \text{atm})} = \boxed{0.40\ \text{L}}$

$V_1 = 3.0$ L $V_2 = ?$ L

E2) 14.5 L of gas has a pressure of 850. mm Hg. The gas is then allowed to expand to a volume of 20.0 L what is the new pressure?

$P_1 = 850.$mmHg $P_2 = ?$ mmHg $P_1V_1 = \boxed{P_2}V_2$ $\dfrac{P_1V_1}{V_2} = P_2$

$V_1 = 14.5$ L $V_2 = 20.0$ L

$$\frac{(850.\ \text{mm Hg})(14.5\ \text{L})}{(20.0\ \text{L})} = \boxed{616\ \text{mm Hg}}$$

V. Charles' Law

A. **CHARLES' LAW**: for a gas a constant pressure, volume and temperature are directly proportional. V α T

B. equation:

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$ **Temps must be in Kelvin.**

C. examples

E3) A piston drum container of He at 25.0 °C has a volume of 10.0 L. If it is heated to 150.0 °C, how large is the new volume? Pressure is constant.

$T_1 = 25.0+273 = 298$ K $T_2 = 150.0+273 = 423$ K $\dfrac{V_1}{T_1} = \dfrac{\boxed{V_2}}{T_2}$ $\dfrac{V_1T_2}{T_1} = \boxed{V_2}$

$V_1 = 10.0$ L $V_2 = ?$ L

$$\frac{(10.0\ \text{L})(423\ \text{K})}{(298\ \text{K})} = \boxed{14.2\ \text{L}}$$

E4) A sample of chlorine gas occupies 7.50 L at 62.0 °C. If pressure is held constant, how low must the temperature drop to allow the gas to occupy 0.250 L?

$T_1 = 62.0+273 = 335$ K $T_2 = ?$ K $\dfrac{V_1}{T_1} = \dfrac{V_2}{\boxed{T_2}}$ $V_1\boxed{T_2} = V_2T_1$ $\boxed{T_2} = \dfrac{V_2T_1}{V_1}$

$V_1 = 7.50$ L $V_2 = 0.250$ L

$$\frac{(0.250\ \text{L})(335\ \text{K})}{(7.50\ \text{L})} = \boxed{11.2\ \text{K}}$$

VI. Gay-Lussac's Law

A. **GAY-LUSSAC'S LAW**: for a gas a constant volume, pressure and temperature are directly proportional. P α T

B. equation:

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$ **Temps must be in Kelvin.**

C. examples

E5) A sample of O_2 gas has a pressure of 475.0 mm Hg at 38.5 °C. If the temperature is raised to 85.2 °C and the volume is unchanged, what is the new pressure?

P_1 = 475.0 mm Hg P_2 = ? mm Hg

T_1 = 38.5+273 = 312 K T_2 = 85.2+273 = 358 K

$$\frac{P_1}{T_1} = \frac{\boxed{P_2}}{T_2} \qquad P_1T_2 = T_1\boxed{P_2} \qquad \frac{P_1T_2}{T_1} = \boxed{P_2}$$

$$\frac{(475.0 \text{ mm Hg})(358 \text{ K})}{(312 \text{ K})} = \boxed{545 \text{ mm Hg}}$$

E6) A container of methane gas at 511 °C has a pressure of 466.9 kPa. How low must the temperature be for the pressure to become 101.3 kPa? Volume is constant.

P_1 = 466.9 kPa P_2 = 101.3 kPa

T_1 = 511+273 = 784 K T_2 = ? K

$$\frac{P_1}{T_1} = \frac{P_2}{\boxed{T_2}} \qquad P_1\boxed{T_2} = T_1P_2 \qquad \boxed{T_2} = \frac{T_1P_2}{P_1}$$

$$\frac{(784 \text{ K})(101.3 \text{ kPa})}{(466.9 \text{ kPa})} = \boxed{170. \text{ K}}$$

VII. The **COMBINED GAS LAW**

A. combination of Boyle's, Charles' and Gay-Lussac's Laws.

B. no constants

C. equation and tips:

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

Temps must be in Kelvin.

Combined Gas Law

"Potato Chips are Very Good To Bite." **(from Mr. D. Noyes, CCCHS, 1982)**

Pressure constant – Charles   **Volume constant – Gay-Lussac**

Temperature constant – Boyle

D. examples

E7) 2.00 L of a gas at 30.3 °C has a pressure of 1.77 atm. The gas is heated to 50.9 C, and a 4.01 atm pressure is observed. What is the new volume of the gas?

P_1 = 1.77 atm P_2 = 4.01 atm

V_1 = 2.00 L V_2 = ? L

T_1 = 30.3 + 273 = 303 K T_2 = 50.9 + 273 = 324 K

$$\frac{P_1V_1}{T_1} = \frac{P_2\boxed{V_2}}{T_2} \qquad \frac{P_1V_1T_2}{T_1\,P_2} = \boxed{V_2}$$

$$\frac{(1.77 \text{ atm})(2.00 \text{ L})(324 \text{ K})}{(303 \text{ K})(4.01 \text{ atm})} = \boxed{0.944 \text{ L}}$$

E8) A 7.50 L sample of N_2 gas in a piston container is measured at 244.8 kPa and 24.2 °C, If the pressure increases to 300.0 kPa and the volume is increased to 9.00 L, what is the Kelvin temperature of the gas?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{\boxed{T_2}} \qquad P_1V_1\boxed{T_2} = T_1P_2V_2$$

P_1 = 244.8 kPa P_2 = 300.0 kPa

V_1 = 7.50 L V_2 = 9.00 L

T_1 = 24.2+273 = 297 K T_2 = ? K

$$\boxed{T_2} = \frac{T_1P_2V_2}{P_1V_1} \qquad \boxed{T_2} = \frac{(297 \text{ K})(300.0 \text{ kPa})(9.00 \text{ L})}{(244.8 \text{ kPa})(7.50 \text{ L})} = \boxed{437 \text{ K}}$$

VIII. The IDEAL GAS LAW

A. **IDEAL GAS LAW**: the number of moles of an "ideal" gas can be found when P, V, and T are known.

B. equation:

PV = nRT	
P = pressure	R = ideal gas constant
V = volume	T = Kelvin temperature
n = # of moles	

<u>Values for R, the ideal gas constant</u>: (R varies with the pressure unit)

0.08206	(L atm / mol K)
8.314	(L kPa /mol K), (J/ mol K), (m^3 Pa / mol K)
1.987	(cal / mol K)
62.36	(L mm Hg / mol K), (L torr/ mol K)

C. examples

E9) A container of NO_2 gas occupies 14.0 L at 22.3 °C. The pressure is 75 atm. How many moles of NO_2 are in the container?

P = 75 atm R = 0.08206 L atm/mol K
V = 14.0 L T = 22.3+273 = 295 K
n = ? moles

$$\mathbf{PV = \boxed{n}RT} \qquad \mathbf{\frac{PV}{RT} = \boxed{n}}$$

$$\mathbf{n} = \frac{(75\ \cancel{atm})(14.0\ \cancel{L})}{(0.08206\ \frac{\cancel{L}\ atm}{mol\ \cancel{K}})(295\ \cancel{K})} = \boxed{43\ mol}$$

E10) How many grams of NO_2 gas are in the container in the previous problem?

$$43\ \cancel{mol\ NO_2} \times \frac{[14.0 + 2(16.0)]\ g\ NO_2}{1\ \cancel{mol\ NO_2}} = 1978 = \boxed{2.0 \times 10^3\ g\ NO_2}$$

D. REAL vs. IDEAL GAS

1) **REAL GAS**—*any gas found in nature or made synthetically*
2) **IDEAL GAS**—*a theoretical gas with a gas with particles of negligible mass and no attraction for one another (always follows the gas laws)*
3) at many temp. and pressure conditions, real gases behave like ideal gases

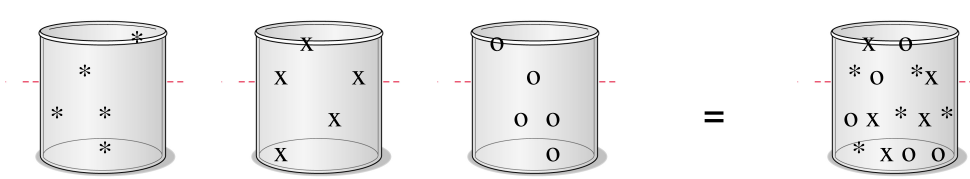
IX. Dalton's Law of Partial Pressures

A. **DALTON'S LAW OF PARTIAL PRESSURES**: *At constant temperature and volume, the total pressure exerted by a mixture of gases equals the sum of the pressures exerted by each individual gas.*

B. equation

$$\mathbf{P_{TOTAL} = P_1 + P_2 + P_3\ldots}$$

Volume and temp must be constant.



900 mm Hg 200 mm Hg 500 mm Hg 1600 mm Hg

C. examples

E11) Give the total pressure of a mixture of gases if the partial pressures are 1.9 atm and 3.5 atm.

$\boxed{\mathbf{P_{TOTAL}}} = \mathbf{P_1 + P_2}$ $\quad\quad$ $\mathbf{P_{TOTAL}}$ = 1.9 atm + 3.5 atm = $\boxed{5.4 \text{ atm}}$

E12) What is the partial pressure of Xe gas in a 750.0 kPa mixture of He at 200.0 kPa, and Rn at 105.5 kPa, and Xenon?

$\mathbf{P_{TOTAL} = P_{He} + P_{Rn} +} \boxed{\mathbf{P_{Xe}}}$ $\quad$ 750.0 kPa = 200.0 kPa + 105.5 kPa + $\mathbf{P_{Xe}}$ $\quad$ $\mathbf{P_{Xe}}$ = $\boxed{444.5 \text{ kPa}}$

X. Avogadro's Principle

A. **<u>AVOGADRO'S PRINCIPLE</u>**: *equal volumes of gases at the same temperature and pressure contain equal numbers of particles*

B. gases have a very large amount of space between the particles

C. review: at STP (273 K and 1 atm), 1 mol of any gases occupies 22.4 L

D. examples

E13) Calculate the volume occupied by 26 g of sulfur dioxide gas at STP.

$$26 \text{ \sout{g SO}}_2 \times \frac{1 \text{ \sout{mol SO}}_2}{64.1 \text{ \sout{g SO}}_2} \times \frac{22.4 \text{ L SO}_2}{1 \text{ \sout{mol SO}}_2} = \boxed{9.1 \text{ L SO}_2}$$

E14) How many particles of Ar gas are in 200.7 L Ar at STP? (specify which type of particle)

$$200.7 \text{ \sout{L Ar}} \times \frac{1 \text{ mol Ar}}{22.4 \text{ L Ar}} \times \frac{6.02 \times 10^{23} \text{ atoms Ar}}{1 \text{ mol Ar}} = \boxed{5.39 \times 10^{24} \text{ atoms Ar}}$$