Ch. 12 Notes - GASES

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

STANDARD ATMOSPHERIC PRESSURE:

1* atm   760* mm Hg   760* torr   101.3 kPa   14.7 psi

* atm, mm Hg, torr are exact values

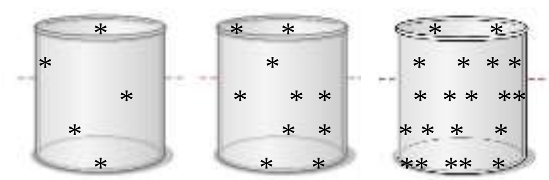
I. Adding or removing a gas

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

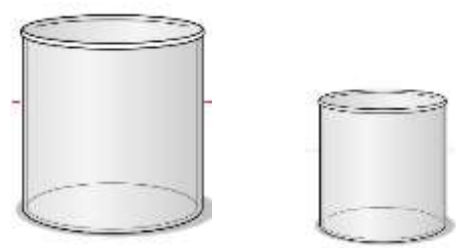
II. Changing container size

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*

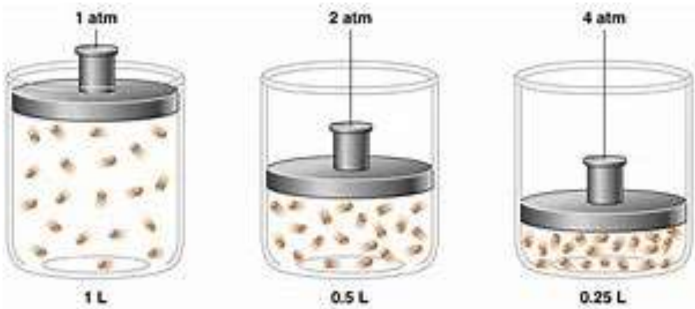
P *= pressure*   ***V*** *= volume*   ***T*** *= temperature*   ***n*** *= # of moles*   ***R*** *= a constant*

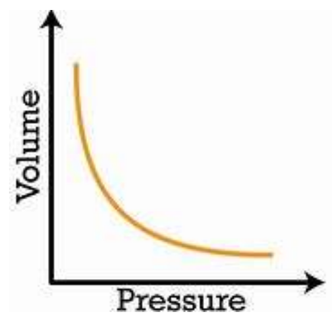
Tip for math success:
Rearrange the equation in symbols before plugging in the numbers and units.

IV. Boyle's Law (Robert Boyle, 1627-1691)

A. **<u>Boyle's Law</u>**: *for a gas a constant temperature, pressure and volume are indirectly or inversely proportional.* $P \alpha 1/V$

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





Source: prenhall

C. examples

EXAMPLE 1) A sample of CO gas is at 0.66 atm in a 3.0 L piston container at a constant temperature. If the pressure is increased to 5.0 atm, what is the new volume?

P_1 = 0.66 atm
V_1 = 3.0 L
P_2 = 5.0 atm
V_2 = ? L

$\mathbf{P_1V_1 \quad P_2\boxed{V_2}}$ $\quad \mathbf{\frac{P_1V_1}{P_2} = V_2}$ $\quad \frac{(0.66\ \cancel{atm})(3.0\ L)}{(5.0\ \cancel{atm})} = \boxed{0.40\ L}$

EXAMPLE 2) 14.5 L of gas has a pressure of 850. mm Hg. If the gas is allowed to expand to a volume of 20.0 L, what is the new pressure?

P_1 = 850. mmHg
V_1 = 14.5 L
P_2 = ? mmHg
V_2 = 20.0 L

$\mathbf{P_1V_1 = \boxed{P_2}V_2}$ $\quad \mathbf{\frac{P_1V_1}{V_2} = P_2}$

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

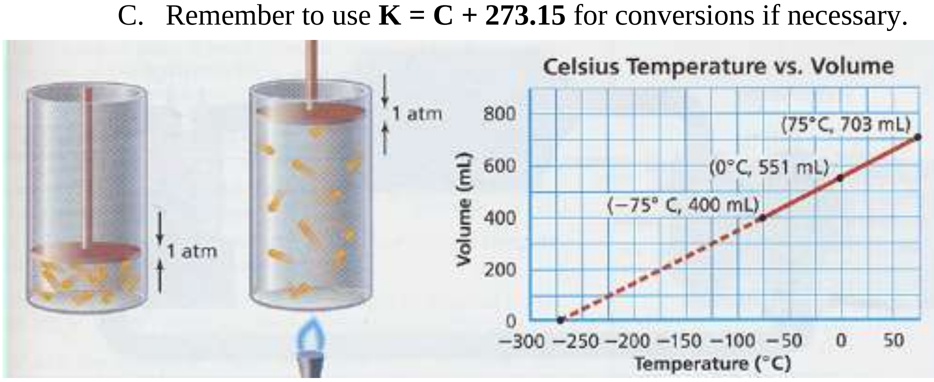
V. Charles' Law (Jacques Charles, 1746-1823)

A. **<u>Charles' Law</u>**: *for a gas a constant pressure, volume and temperature are directly proportional.* $V \alpha T$

B. equation:

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

C. Remember to use **K = C + 273.15** for conversions if necessary.



Source: boomeria

D. examples

EXAMPLE 3) 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, what is the new volume?

$V_1 = 10.0$ L
$T_1 = 25.0+273.15 = 298.2$ K

$V_2 = ?$ L
$T_2 = 150.0+273.15 = 423.2$ K

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

$$\frac{(10.0\ \text{L})(423.2\ \text{K})}{(298.2\ \text{K})} = \boxed{14.2\ \text{L}}$$

EXAMPLE 4) A sample of chlorine gas occupies 7.50 L at 62.00 °C. If pressure is held constant, what is the temperature which will allow the gas to occupy 0.250 L?

$V_1 = 7.50$ L
$T_1 = 62.00+273.15 = 335.15$ K

$V_2 = 0.250$ L
$T_2 = ?$ K

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

$$\frac{(0.250\ \text{L})(335.15\ \text{K})}{(7.50\ \text{L})} = \boxed{11.2\ \text{K}}$$

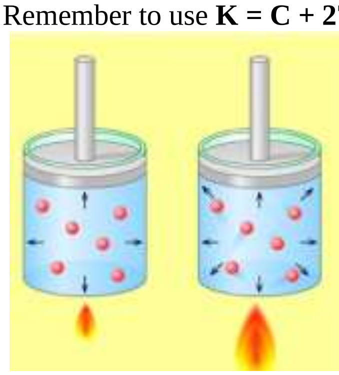
VI. Gay-Lussac's Law (Joseph Gay-Lussac, 1778-1850)

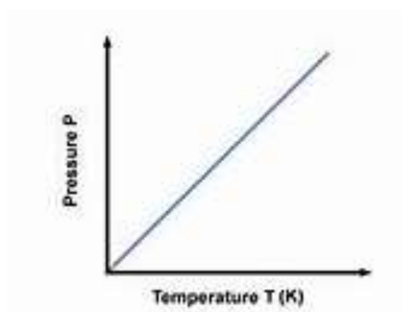
A. **<u>Gay-Lussac's Law</u>**: *for a gas a constant volume, pressure and temperature are directly proportional.* *P α T*

B. equation:

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

C. Remember to use **K = C + 273.15** for conversions if necessary.





Source: Cummings

D. examples

EXAMPLE 5) 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
$T_1 = 38.5+273.15 = 311.7$ K

$P_2 = ?$ mm Hg
$T_2 = 85.2+273.15 = 358.4$ K

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

$$\frac{(475.0\ \text{mm Hg})(358.4\ \text{K})}{(311.7\ \text{K})} = \boxed{546.2\ \text{mm Hg}}$$

EXAMPLE 6) A container of methane gas at 511 °C has a pressure of 466.9 kPa. What must the temperature be for the pressure to become 101.3 kPa?

P_1 = 466.9 kPa
T_1 = 511+273.15 = 784 K
P_2 = 101.3 kPa
T_2 = ? K

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

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

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.

The Combined Gas Law "Who's Who?" (Chem 1H)		
"**P**otato **C**hips	are **V**ery **G**ood	**T**o **B**ite."
Pressure constant – Charles	Volume constant – Gay-Lussac	Temperature constant – Boyle

D. Remember to use **K = C + 273.15** for conversions if necessary.

E. examples

EXAMPLE 7) 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
V_1 = 2.00 L
T_1 = 30.3 + 273.15 = 303.5 K
P_2 = 4.01 atm
V_2 = ? L
T_2 = 50.9 + 273.15 = 324.1 K

$$\frac{P_1V_1}{T_1} = \frac{P_2\boxed{V_2}}{T_2} \qquad \frac{P_1V_1T_2}{T_1P_2} = \boxed{V_2}$$

$$\frac{(1.77\ \cancel{\text{atm}})(2.00\ \text{L})(324.1\ \cancel{\text{K}})}{(303.5\ \cancel{\text{K}})(4.01\ \cancel{\text{atm}})} = \boxed{0.943\ \text{L}}$$

EXAMPLE 8) A 7.50 L sample of N_2 gas in a piston container is measured at 244.8 kPa and 24.20 °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?

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

P_1 = 244.8 kPa
V_1 = 7.50 L
T_1 = 24.20+273.15 = 297.35 K
P_2 = 300.0 kPa
V_2 = 9.00 L
T_2 = ? K

$$\frac{(297.35\ \text{K})(300.0\ \cancel{\text{kPa}})(9.00\ \cancel{\text{L}})}{(244.8\ \cancel{\text{kPa}})(7.50\ \cancel{\text{L}})} = \boxed{437\ \text{K}}$$

EXAMPLE 9) A gas at 298.0 K occupies 40.00 dm^3 at 717.0 mm Hg. The gas is heated to 500.0 K, and the gas expands to 50.00 dm^3. What is the pressure of the gas under the new conditions?

P_1 = 717.0 mm Hg
V_1 = 40.00 dm^3
T_1 = 298.0 K
P_2 = ? mm Hg
V_2 = 50.00 dm^3
T_2 = 500.0 K

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

$$\frac{(717.0\ \cancel{mm\ Hg})(40.00\ \cancel{dm^3})(500.0\ \cancel{K})}{(298.0\ \cancel{K})(50.00\ \cancel{dm^3})} = \boxed{962.4\ mm\ Hg}$$

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	

Values for R, the ideal gas constant: (R varies with the pressure unit)

0.08206	(L atm / mol K)
8.314	(L kPa /mol K)
62.36	(L mm Hg / mol K) or (L torr/ mol K)

C. examples

EXAMPLE 10) A container of nitrogen dioxide gas occupies 14.0 L at 22.3 °C. The pressure is 75.5 atm. How many moles of gas are in the container?

P = 75.5 atm
V = 14.0 L
n = ? moles
R = 0.08206 L atm/mol K
T = 22.3+273.15 = 295.5 K

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

$$\frac{(75.5\ \cancel{atm})(14.0\ \cancel{L})}{(0.08206\ \frac{\cancel{L\ atm}}{mol\ \cancel{K}})(295.5\ \cancel{K})} = \boxed{43.6\ mol}$$

EXAMPLE 11) How many particles of gas are in the container in the previous problem?

$$43.6\ \cancel{mol\ NO_2} \times \frac{6.02 \times 10^{23}\ molec.\ NO_2}{1\ \cancel{mol\ NO_2}} = \boxed{2.62 \times 10^{25}\ molecules\ NO_2}$$

D. Real vs. Ideal Gases

1) **Real Gas**—*any gas found in nature or made synthetically*

2) **Ideal Gas**

- *a theoretical gas with particles of negligible mass and no attraction for one another*
- *always follows the gas laws*
- *follows the KMT*

3) at most temp. and pressure conditions, real gases behave like ideal gases

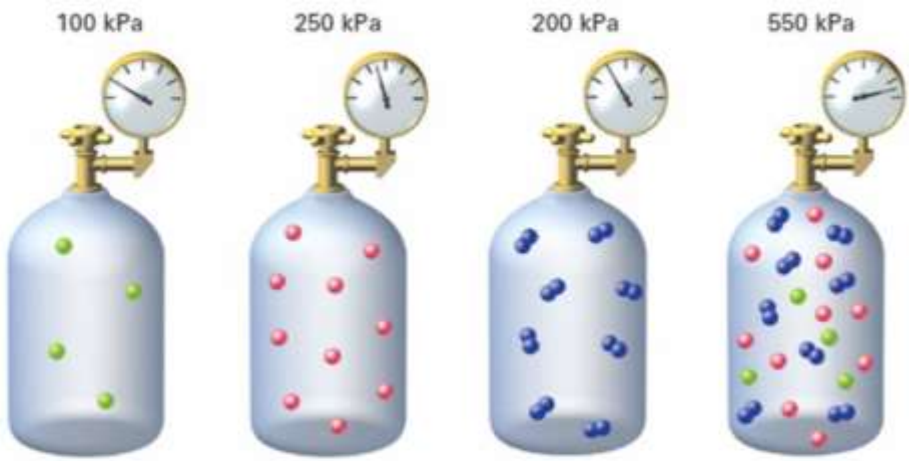
IX. Dalton's Law of Partial Pressures

A. **<u>Dalton's Law of Partial Pressures</u>**: *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.

GAS A + GAS B + GAS C = TOTAL MIXTURE



*** Chem 1H – You may be given a partial pressure problem where the pressures are in different units and you have to convert them to the unit specified in the problem by standard pressure DA. Remember that the standard values for atm, mm Hg, and torr are exact sig.figs. ***

C. examples

EXAMPLE 12) What is the total pressure of a mixture of gases, in kPa, if the partial pressures are the following values?

GAS A = 3. 55 atm
GAS B = 899.0 torr
GAS C = 20.7 psi
GAS D = 222.2 mm Hg
GAS E = 95.00 kPa

$$\text{GAS A} = 3.55\ \cancel{\text{atm}} \times \frac{101.3\text{ kPa}}{1\ \cancel{\text{atm}}} = 360.\text{ kPa}$$

$$\text{GAS B} = 899.0\ \cancel{\text{torr}} \times \frac{101.3\text{ kPa}}{760\ \cancel{\text{torr}}} = 119.8\text{ kPa}$$

$$\text{GAS C} = 20.7\ \cancel{\text{psi}} \times \frac{101.3\text{ kPa}}{14.7\ \cancel{\text{psi}}} = 143\text{ kPa}$$

$$\text{GAS D} = 222.2\ \cancel{\text{mm Hg}} \times \frac{101.3\text{ kPa}}{760\ \cancel{\text{mm Hg}}} = 29.62\text{ kPa}$$

GAS E = 95.00 kPa

TOTAL PRESSURE = 360. + 119.8 + 143 + 29.62 + 95.00 = $\boxed{747\text{ kPa}}$

EXAMPLE 13) Give the total pressure of a mixture of gases if the partial pressures are 1.9 atm and 3.5 atm.

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

EXAMPLE 14) 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?

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

X. Avogadro's Principle

A. **Avogadro's Principle**: *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 (273.15 K and 1atm), 1 mol of any gases occupies 22.4 L

D. examples

EXAMPLE 15) Calculate the volume occupied by 26 g of sulfur dioxide gas at STP.

$$26\ \cancel{g\ SO_2} \times \frac{1\ \cancel{mol\ SO_2}}{64.07\ \cancel{g\ SO_2}} \times \frac{22.4\text{ L } SO_2}{1\ \cancel{mol\ SO_2}} = \boxed{9.1\text{ L } SO_2}$$

EXAMPLE 16) How many particles of argon gas are in 200.7 L argon at STP?

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

XI. Gas Stoichiometry – see Ch. 10

Mole-volume	mol A → L B	gases at STP
Volume-mole	L A → mol B	gases at STP
Volume-volume	L A → L B	gases at STP
Volume-Particle	L A → r.p. B	gases at STP; specify type of r.p
Particle-Volume	r.p. A → L B	specify type of r.p; gases at STP
Mass-Volume	g A → L B	molar masses to 0.01 g; gases at STP
Volume-Mass	L A → g B	gases at STP; molar masses to 0.01 g