Thermal & Statistical Physics
PHYS 343

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Lecture 5

Kinetic Theory of Gases

Ideal Gas Model

Ideal Gas Model

Gas Laws

Gas Laws

- (1) When temperature is held constant, the density of a gas is proportional to pressure, and volume is inversely proportional to pressure. Accordingly, an increase in pressure will cause an increase in density of the gas and a decrease in its volume. - **Boyles's Law**

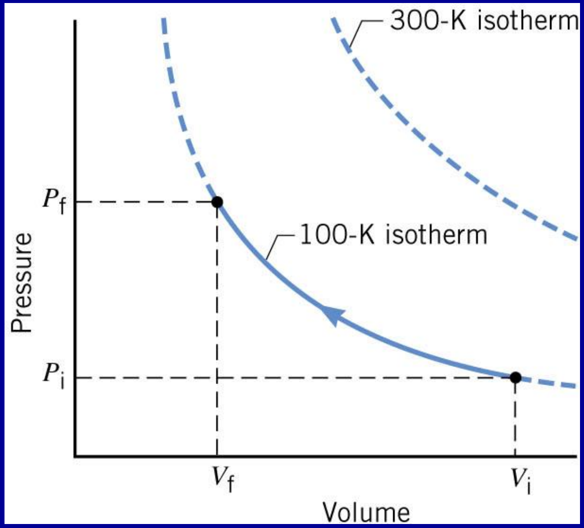
- (2) If volume is kept constant, the pressure of a unit mass of gas is proportional to temperature. If temperature increase so will pressure, assuming no change in the volume of the gas.

- (3) Holding pressure constant, causes the temperature of a gas to be proportional to volume, and inversely proportional to density. Thus, increasing temperature of a unit mass of gas causes its volume to expand and its density to decrease as long as there is no change in pressure. - Charles's Law

Boyle's law

At constant temperature, the pressure is inversely proportional to the volume.

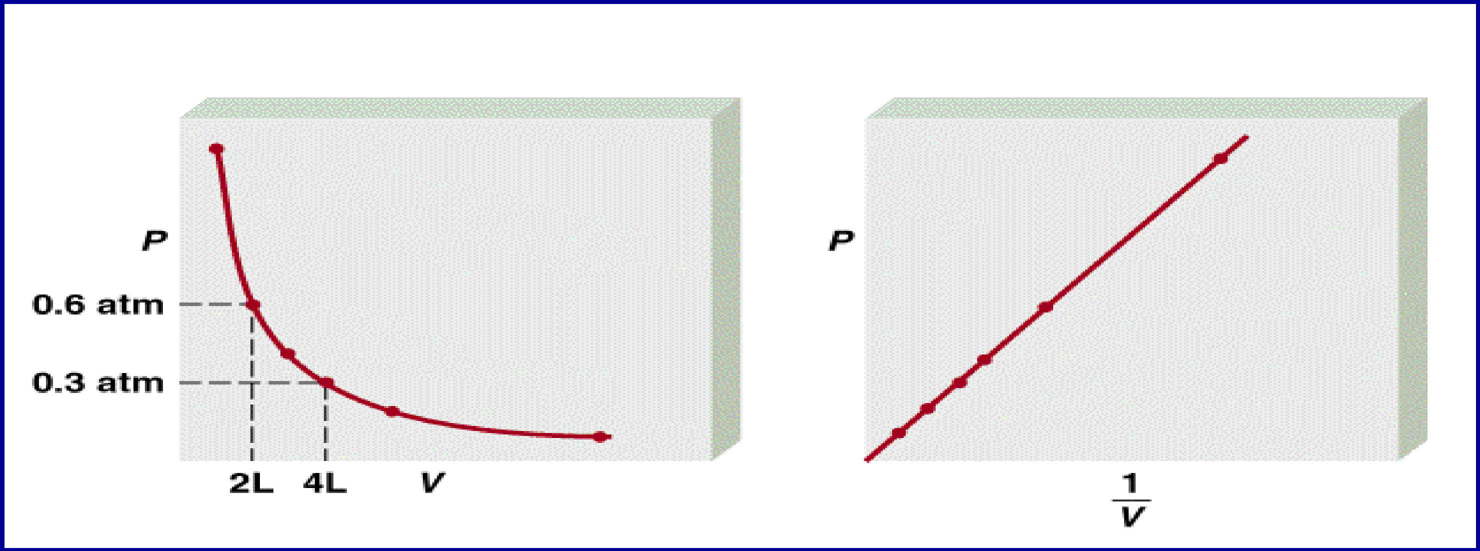
$$P \propto 1/V$$



The pressure is also proportional to the amount of gas.

$$P \propto n$$

Boyle's law



$P \propto 1/V$

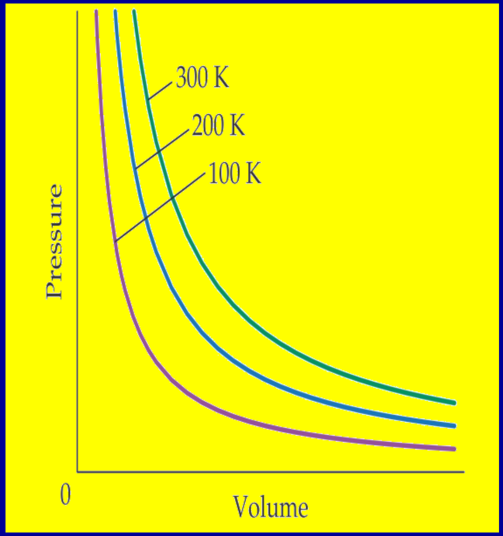
$P \times V = \text{constant}$

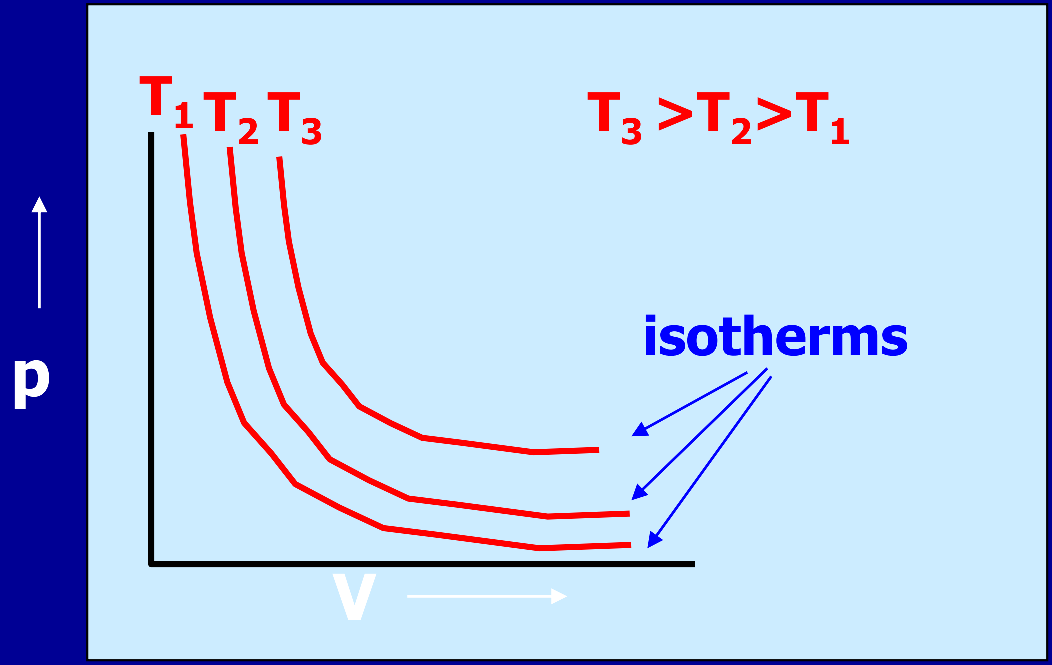
$P_1 \times V_1 = P_2 \times V_2$

Constant temperature
Constant amount of gas

Boyle's Law

- Hyperbolic Relation Between Pressure and Volume

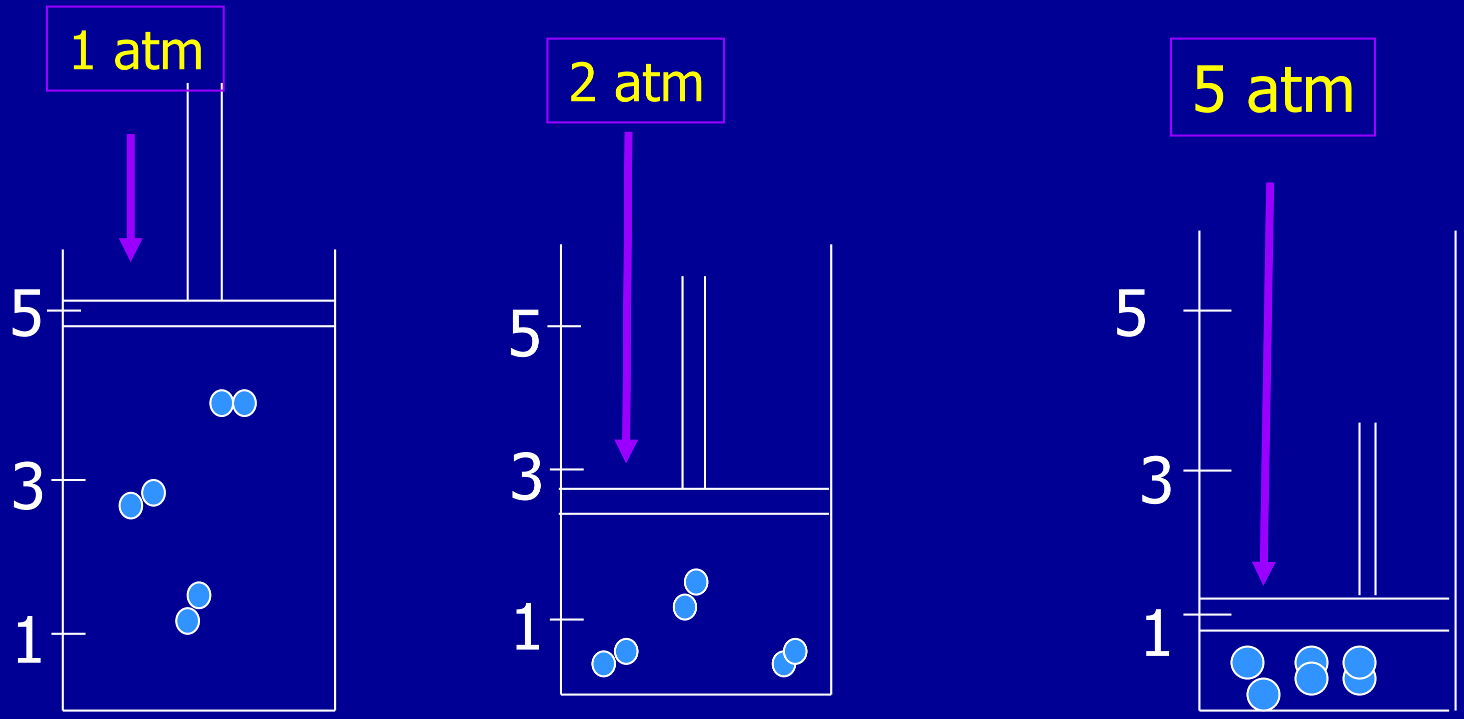




p – V Diagram

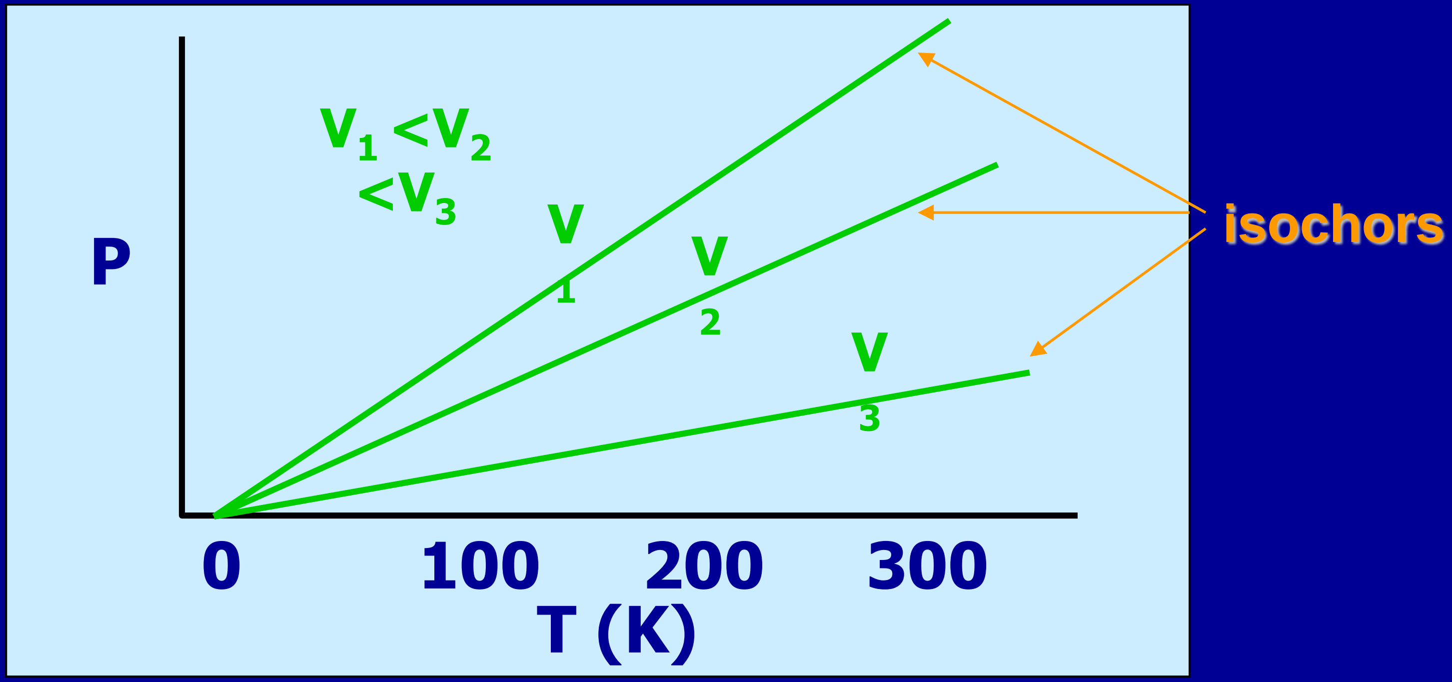
Effect of Pressure on Volume

Boyle's Law



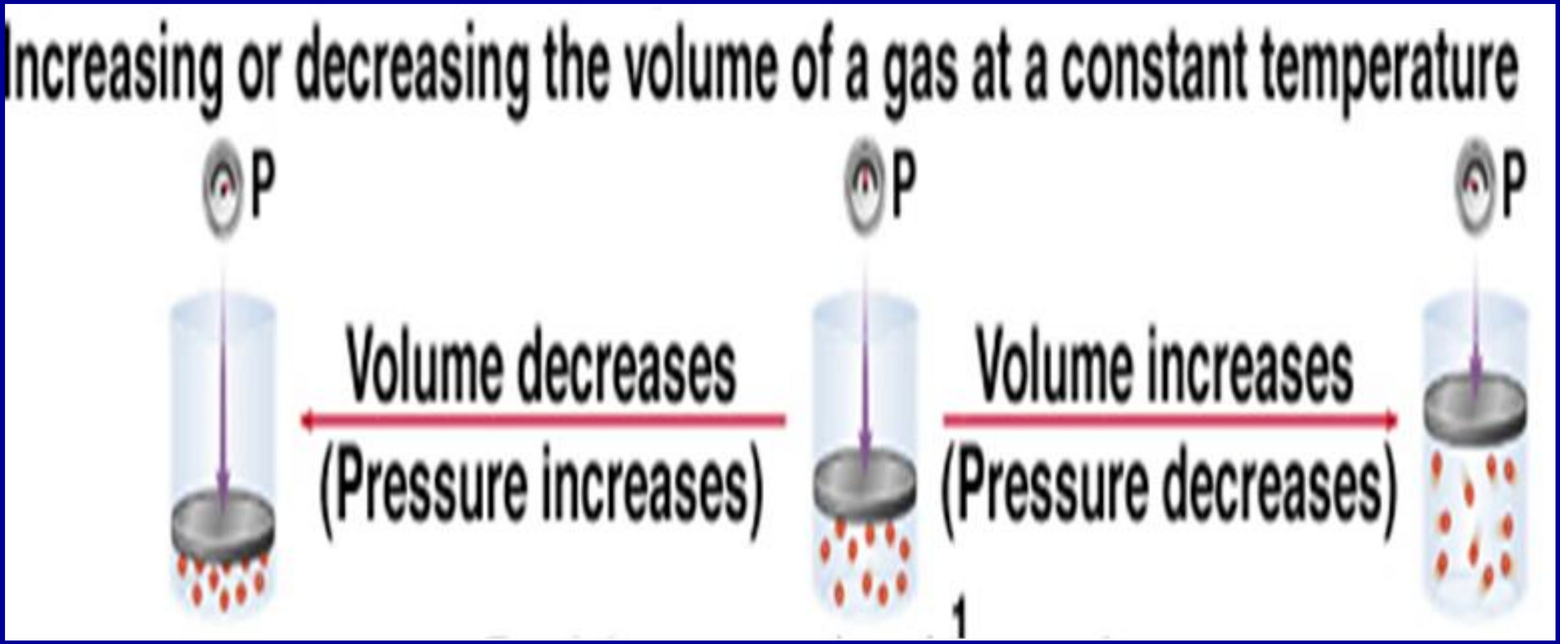
Charles' Law

- Linear Relation Between Temperature and Pressure

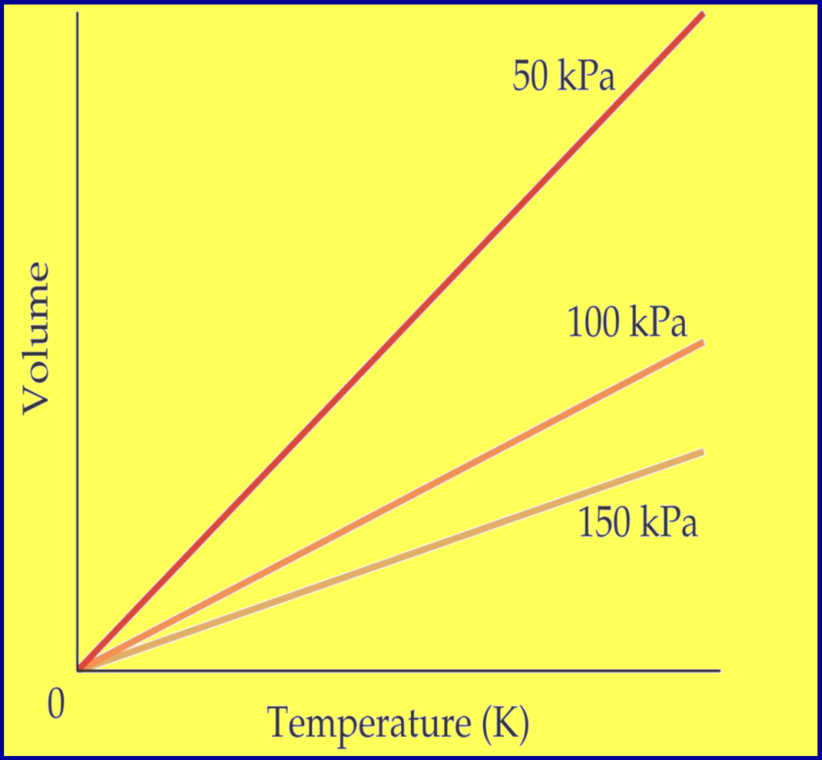


P – T Diagram

Charles' Law


Increasing or decreasing the volume of a gas at a constant temperature
P
P
P
Volume decreases
(Pressure increases)
Volume increases
(Pressure decreases)

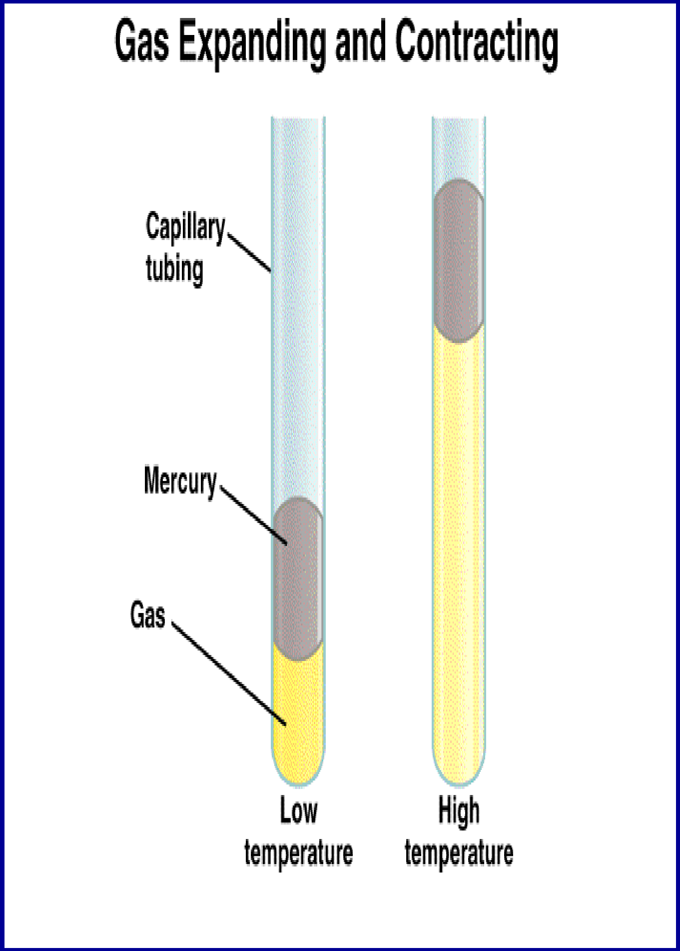
Charles' Law



Real data must be obtained above liquefaction temperature.

Experimental curves for different gasses, different masses, different pressures all extrapolate to a common zero.

Charles' Law



$V \propto T$

$V = kT$

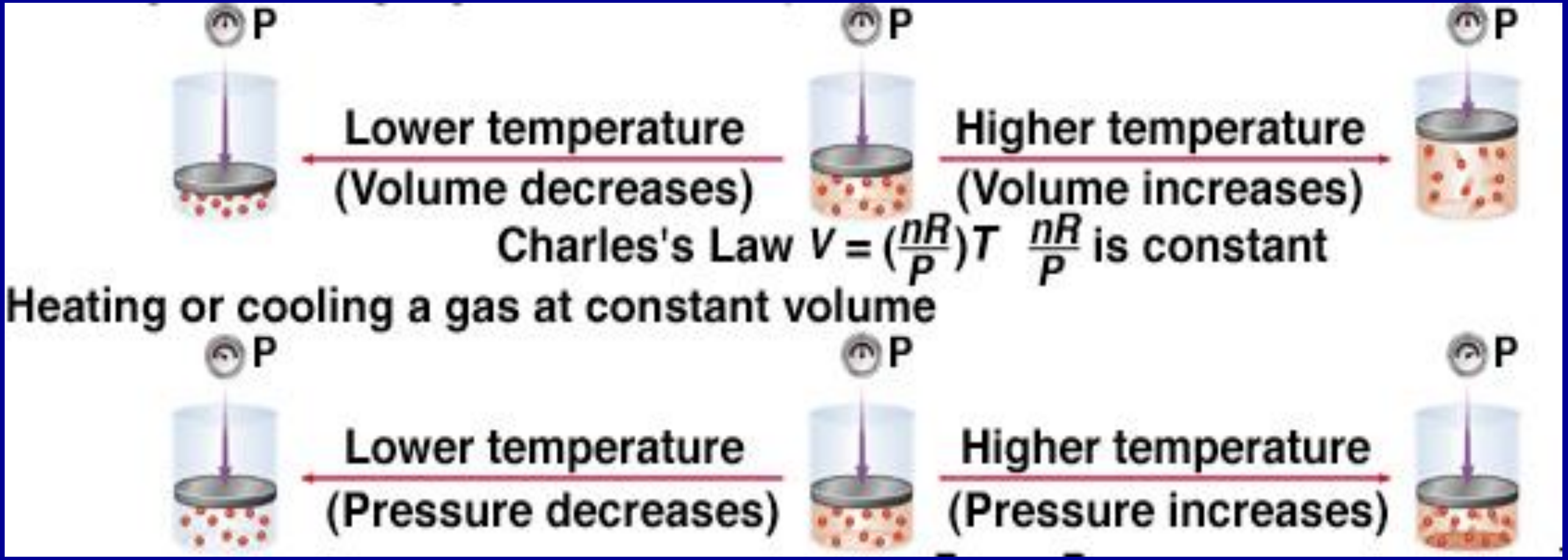
$V/T = k$

$V_1/T_1 = V_2/T_2$

Constant pressure
Constant amount of gas

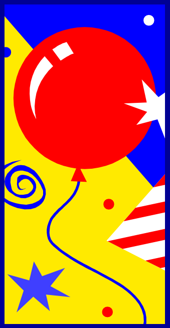
As T increases, V Increases

Charles' Law

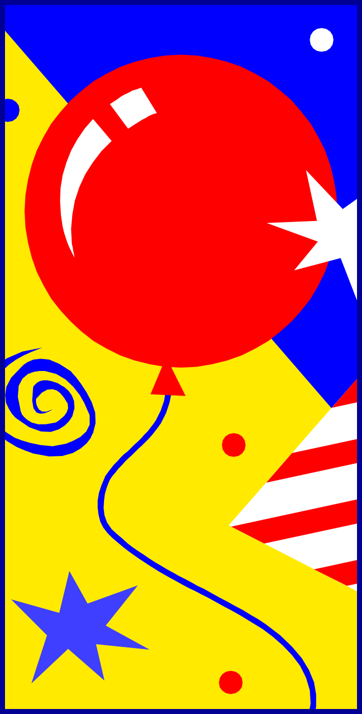

P
P
P
Lower temperature
(Volume decreases)
Higher temperature
(Volume increases)
Charles's Law $V = (\frac{nR}{P})T$ $\frac{nR}{P}$ is constant
Heating or cooling a gas at constant volume
P
P
P
Lower temperature
(Pressure decreases)
Higher temperature
(Pressure increases)

Effect of Temperature on Volume

Charles' Law

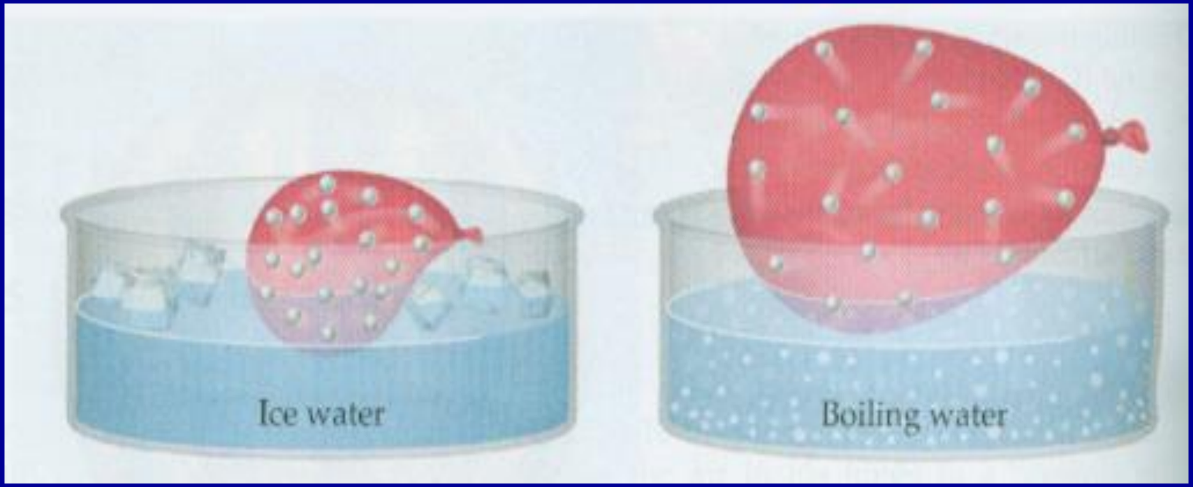


Low Temperature



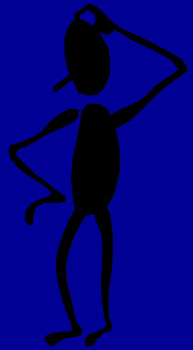
High Temperature

The Volume of a gas increases with and increase in temperature.



Introductory Chemistry; 2nd Ed; by Nivaldo Tro; Prentice Hall Publishing 2006, p356

A sample of chlorine gas occupies a volume of 946 mL at a pressure of 726 mmHg. What is the pressure of the gas (in mmHg) if the volume is reduced at constant temperature to 154 mL?



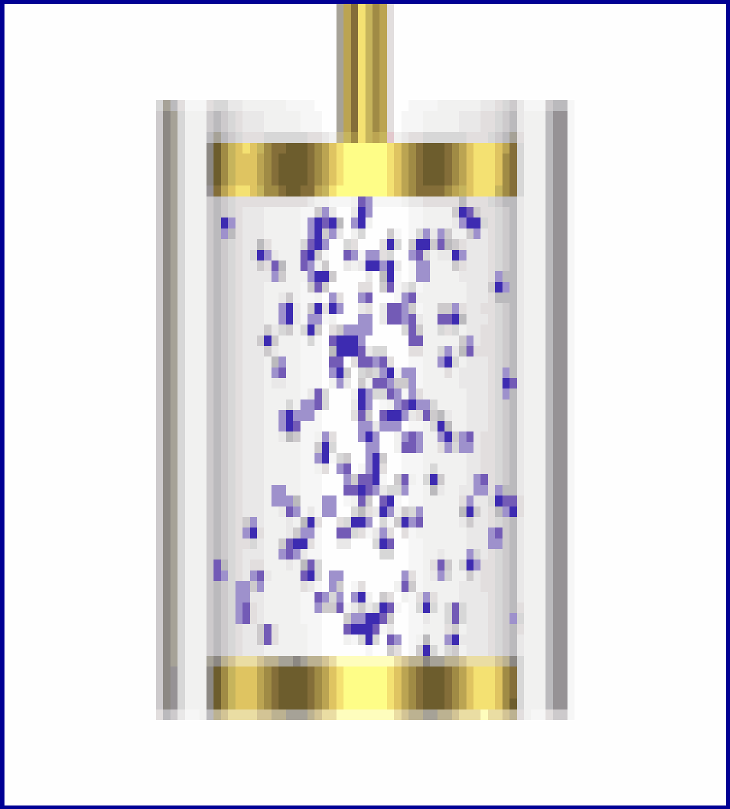
$$P_1 \times V_1 = P_2 \times V_2$$

P_1 = 726 mmHg P_2 = ?

V_1 = 946 mL V_2 = 154 mL

$$P_2 = \frac{P_1 \times V_1}{V_2} = \frac{726 \text{ mmHg} \times 946 \text{ mL}}{154 \text{ mL}} = 4460 \text{ mmHg}$$

Compression and expansion of adiabatically isolated gas is accompanied by its heating and cooling.



Dalton's Law

Pressure each gas in a mixture would exert if it were the only gas in the container

Dalton's Law of Partial Pressures

The total pressure exerted by a gas mixture is the sum of the partial pressures of the gases in that mixture.

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

Partial Pressures

The total pressure of a gas mixture depends on the total number of gas particles, not on the types of particles.

STP

P = 1.00 atm	**P = 1.00 atm**
1.0 mol He	**0.50 mol O_2 + 0.20 mol He + 0.30 mol N_2**

Dalton's Law…

Suppose we have two gases in a container: n_A moles of gas A and n_B moles of gas B.

We can define individual **partial pressures**

$$p_A = n_A RT/V \text{ and } p_B = n_B RT/V\ .$$

Dalton's Law is that the measured total pressure p is the sum of the partial pressures of all the components:

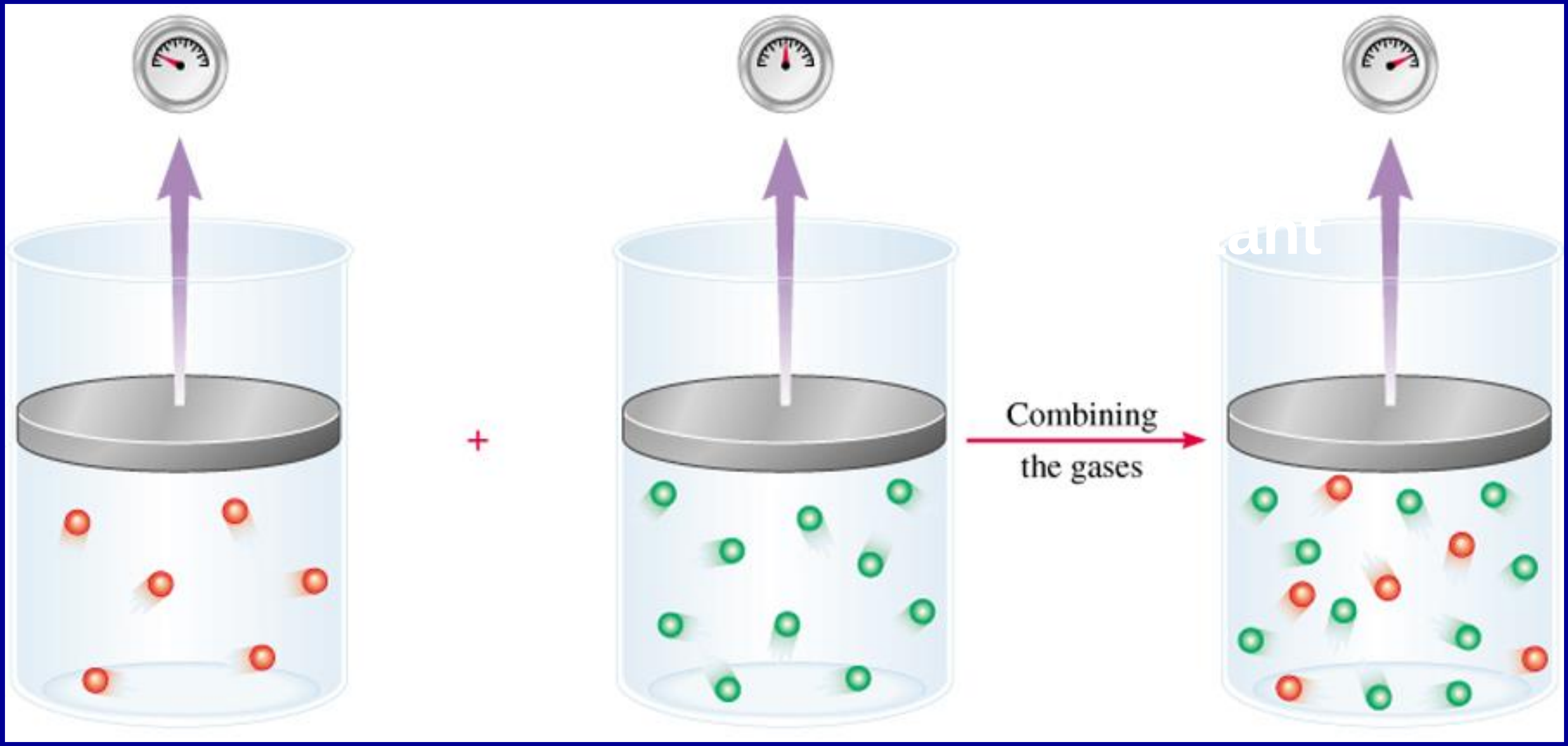
$$p = p_A + p_B + \ldots = (n_A + n_B + \ldots)RT/V.$$

Mole fractions: define x_J for species J as n_J/n

where $n = (n_A + n_B + \ldots)$.

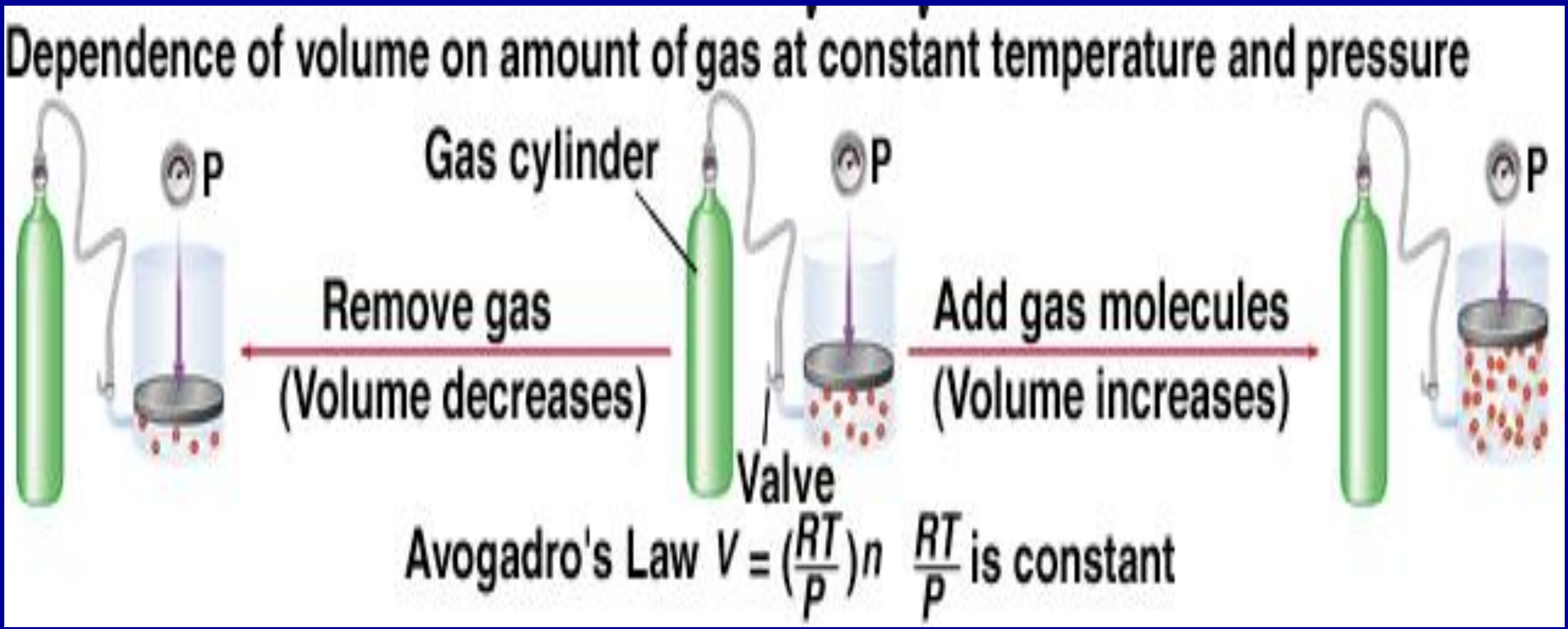
Then, $x_A + x_B + \ldots = 1$ and $p_J = p\, x_J$19

Dalton's Law of Partial...



P_1 P_2 $P_{total} = P_1 + P_2$

Avogadro' Law



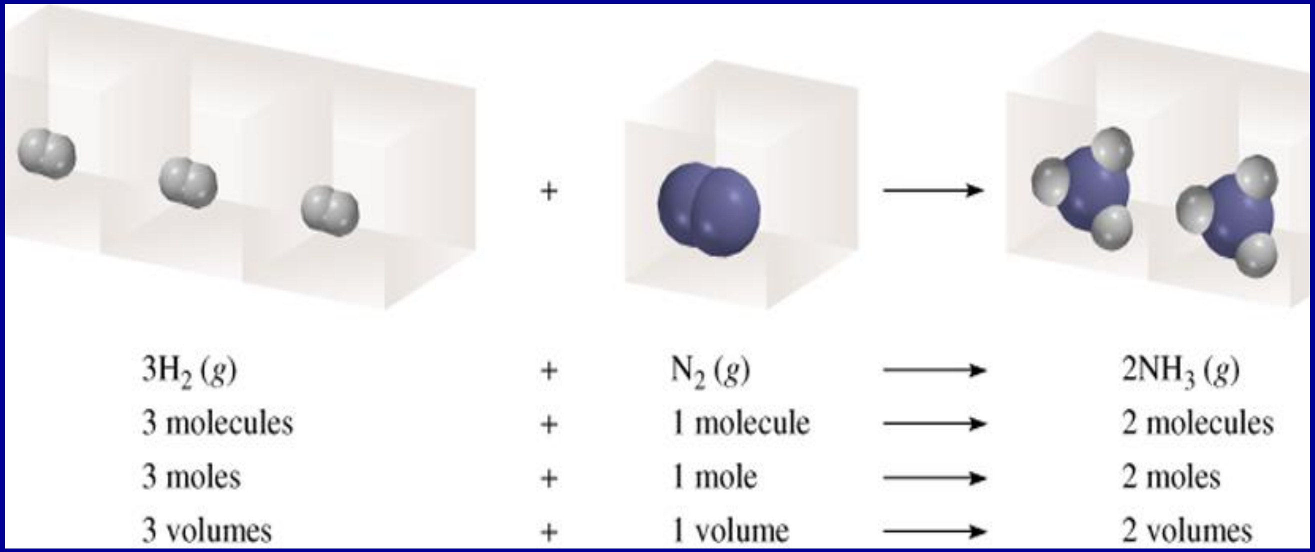
Avogadro's Law

$V \propto$ number of moles (n)

V = constant x n

$V_1/n_1 = V_2/n_2$

Constant temperature
Constant pressure



Learning Check

A 5.00 L scuba tank contains 1.05 mole of O_2 and 0.418 mole He at 25°C. What is the partial pressure of each gas, and what is the total pressure in the tank?

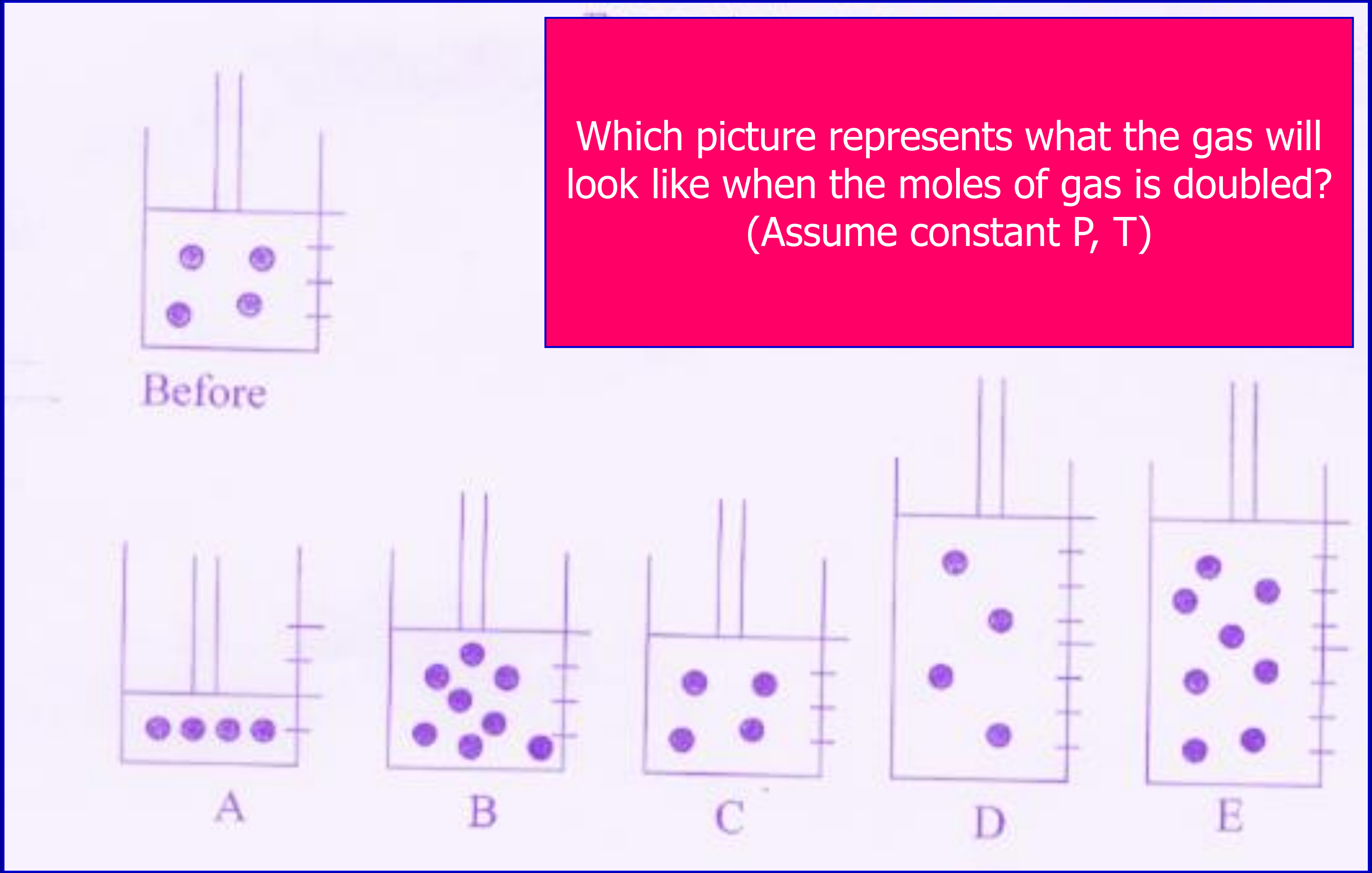
- **Solution**

$$P = \frac{nRT}{V} \qquad P_T = P_{O2} + P_{He}$$

$$P_T = \frac{1.47 \text{ mol} \times 0.0821 \text{ L-atm} \times 298 \text{ K}}{5.00 \text{ L} \quad (\text{K mol})}$$

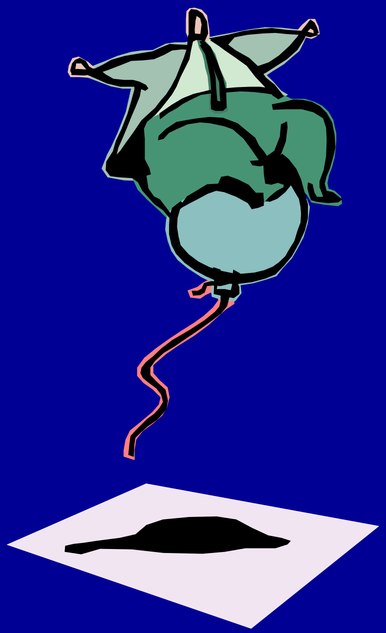
$= 7.19$ atm

Which picture represents what the gas will look like when the moles of gas is doubled? (Assume constant P, T)



Air bag

Conclusion
Gas Laws



- When a gas is kept at a constant temperature, its pressure is inversely proportional to its volume (Boyle's law)
- When a gas is kept at a constant pressure, its volume is directly proportional to its temperature (Charles and Gay-Lussac's law)
- When the volume of the gas is kept constant, the pressure is directly proportional to the temperature (Guy-Lussac's law)