Lecture 5
Chapter 19: The Kinetic Theory of Gases

19-1 Avogadro's number, N_A:

One mole of a substance contains N_A (Avogadro's number) elementary units (usually atoms or molecules).

$$N_A = 6.023 \times 10^{23}$$
 elementary units

Amedeo Avogadro suggested that all gases occupy the same volume under the same conditions of temperature and pressure. All gases contain the same number of atoms or molecules.

1 mole of He contains, $N_A = 6.023 \times 10^{23}$ atoms n mole of He contains total number of atoms, $N = nN_A$ atoms

1 mole of O_2 contains, N_A = 6.023 x 10²³ molecules n mole of O_2 contains, total number of molecules, $N = nN_A$ molecules

One molar mass M of any substance is the mass of one mole of the substance.

 $M = mN_A$ where m is the mass of 1 atom or molecule

n molar mass (sample mass), $M_{sam} = mN = m(nN_A) = n(mN_A) = nM$

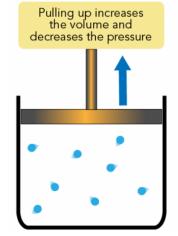
$$\frac{M_{sam}}{M} = \frac{\mathsf{n}(\mathsf{mNA})}{mN_A}$$

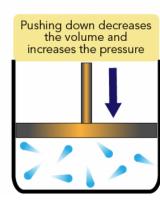
$$n = \frac{M_{Sam}}{M}$$

19-2 Ideal gases:

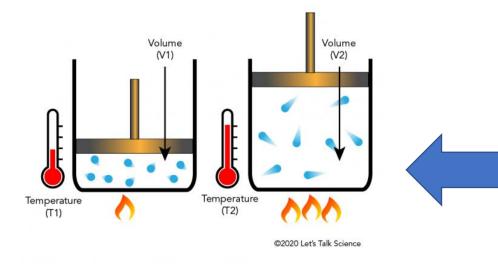
Boyle's Law describes the inverse proportional relationship between pressure and volume at a constant temperature and a fixed amount of gas. This law came from a manipulation of the Ideal Gas Law.

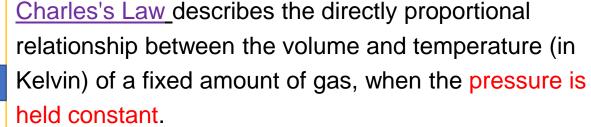












V∝T

19-2 Ideal gases:

By combining two equations and the fact $V \propto n$, we can write the ideal gas equation

pV=nRT [R in terms of mole]

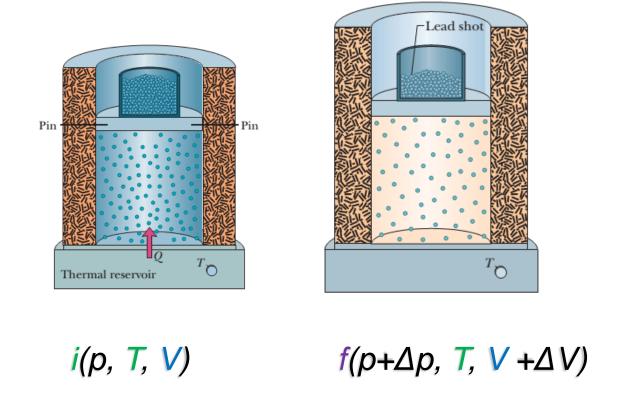
Boltzmann constant, $k = R/N_A$ $N_A k = R$ $\frac{N}{n} k = R$ nR = Nk $[N = nN_A]$

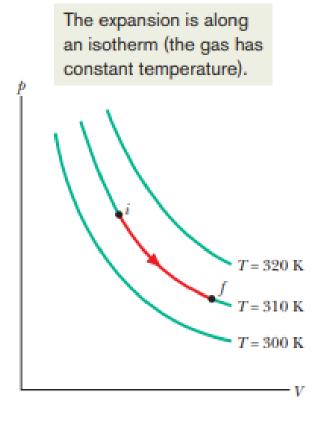
pV=NkT [k in terms of molecule]

Ideal gas: It governs the macroscopic properties. We can deduce many properties of the ideal gas in a simple way. Although there is no such thing in nature as a truly ideal gas, all real gases approach the ideal state at low enough densities their molecules are far enough apart that they do not interact with one another.

19-2-1 Work done by an ideal gas at constant temperature:

Suppose that we allow the ideal gas to expand from an initial volume V_i to a final volume V_f while we keep the temperature T of the gas constant. Such a process, at constant temperature, is called an isothermal expansion (and the reverse is called an isothermal compression).





This is a general expression for the work done during any change in volume of any gas.

$$W = \int_{V_i}^{V_f} \mathbf{p} \ dV$$

For an ideal gas, pV = nRT

$$p = \frac{nRT}{V}$$

$$W = \int_{V_i}^{V_f} \frac{nRT}{V} dV$$

$$W = nRT \int_{V_i}^{V_f} \frac{dV}{V}$$
 [As

$$W = nRT \left[\ln V \right]_{V_i}^{V_f}$$

$$W = nRT \left[\ln V_f - \ln V_i \right]$$

$$W = nRT \ln \frac{V_f}{V_i}$$
 [Isothermal process for an ideal gas]

19-2-2 Work done by an ideal gas at constant volume

If the volume of the gas is constant, then the work done is as follows:

$$W = p\Delta V = p(V-V) = 0$$

$$W = 0$$

19-2-3 Work done by an ideal gas at constant pressure

If the volume changes while the pressure *p* of the gas is held constant, then the work done is as follows:

$$W = \int_{V_i}^{V_f} p \ dV = p \int_{V_i}^{V_f} dV = p \left[V \right]_{V_i}^{V_f} = p \left[V_f - V_i \right]$$

$$W = p \Delta V$$

4. A quantity of ideal gas at 10.0 °C and 100 kPa occupies a volume of 2.50 m³. (a) How many moles of the gas are present? (b) If the pressure is now raised to 300 kPa and the temperature is raised to 30.0 °C, how much volume does the gas occupy? Assume no leaks.

Solution:

(b)
$$p_f V_f = nRT_f$$
(2)

$$V_f = \frac{P_i V_i T_f}{P_f T_i} = \frac{1 \times 10^5 \times 2.50 \times 303.15}{3 \times 10^5 \times 283.15} = \mathbf{0.89} \, \mathbf{m}^3$$

$$OR$$

$$p_f V_f = nRT_f$$

7. Suppose 1.80 mol of an ideal gas is taken from a volume of 3.00 m³ to a volume of 1.50 m³ via an isothermal compression at 30 °C. (a) How much energy is transferred as heat during the compression, and (b) is the transfer *to* or *from* the gas?

Solution:

(a)
$$\Delta E_{int} = Q - W$$

$$E_{int} = \frac{3}{2}nRT$$

$$\Delta E_{int} = \frac{3}{2} nR\Delta T$$

$$\Delta E_{int} = \frac{3}{2} nR(T-T)$$

$$\Delta E_{int} = \frac{3}{2} nR(0)$$

$$\Delta E_{int} = 0$$

$$0 = Q - W$$

$$Q = W$$

[Isothermal process, T= constant]

$$W = nRT \ln(\frac{V_f}{V_i}) = 1.80 \times 8.314 \times 303 \ln(\frac{1.50}{3.00}) = -3140 J$$

$$Q = W$$

$$Q = -3140 J$$

(b) The heat is transferred from the gas.

Sample Problem 19.02 Work by an ideal gas

One mole of oxygen (assume it to be an ideal gas) expands at a constant temperature T of 310 K from an initial volume V_i of 12 L to a final volume V_f of 19 L. How much work is done by the gas during the expansion?