Thermal expansion:

$$\Delta L = \alpha L_0 \Delta T.$$

$$\Delta A = 2\alpha A_0 \Delta T.$$

$$\Delta V = 3\alpha V_0 \Delta T.$$

DENSITY EFFECT:

$$\Delta \rho = -3\alpha \rho_0 \Delta T.$$

NUCLEAR LABELS:

When we speak of ^{12}C, ^{40}Ca or ^{208}Pb we are telling you A, the number of nucleons (p and n) in the nucleus of the atom.

AVOGADRO'S NUMBER: $N_A = 6.02 \times 10^{26}$ constituents per A kg.

IDEAL GAS LAW: $pV = Nk_BT$.

k_B is a fundamental constant relating energy in J to temperature in K.

Note that for a given gas in a given system, pV/T is a constant.

DETAILS AND DEFINITIONS:

Atomic mass unit (u or Da): u is 1/12-th of the mass of a ^{12}C atom, which works out to about 1.66 $\times 10^{-27}$ kg.

Avogadro's Number: $N_A = 6.02214 \times 10^{26}$ is the number of atoms in 12 kg of ^{12}C. This is called a "kilomole."

Gas Constant: $R = 8314$ J/kilomole-K. $R = N_A k_B$.

Boltzmann's Constant: $k_B = 1.381 \times 10^{-23}$ J/K.

The average kinetic energy of a constituent of a system of temperature T is $KE_{\text{avg}} = (3/2)k_B T$.

The internal energy of an "ideal" gas is

$$U = (3/2)N k_B T.$$

Here N is the number of constituents.

What makes a gas "ideal" is the assumption that the atoms or molecules have only kinetic energy, and no potential energy due to interaction with one another. Real gases have a behavior surprisingly close to an ideal gas, unless they are very cold and dense.

$$pV = N k_B T = nRT.$$

INTERNAL ENERGY OF AN IDEAL GAS:

$$U = (3/2)Nk_BT.$$

RMS SPEED OF A MOLECULE:

$$v_{\text{rms}} = \sqrt{3k_BT/m}.$$

The Equipartition Concept:

Every separate degree of freedom in a system at temperature T receives

$$\frac{1}{2}k_BT$$

. Thus a point particle free to move in 3-dimensional space has

$$3 \times \frac{1}{2}k_BT = \frac{3}{2}k_BT$$

of energy.

• Calculate the mass of a ^{12}C atom using Avogadro's number, and using the nucleon mass (1.67×10^{-27} kg).

• What is the pressure of a gas with 10^{27} atoms at 300 K in a volume of a cubic meter?

• What volume is occupied by 1 kilomole of a gas at atmospheric pressure and 273 K?

• A gas at a CONSTANT pressure of 10^6 J/m^3, consisting of 10^{26} molecules, expands its volume by one cubic meter. By how much did its temperature change?

• A gas undergoes a process where $p_2 = p_1/2$, $V_2 = V_1/3$. What is T_2/T_1?

• A gas undergoes a process such that $p_f = p_i/3$, $V_f = V_i/3$, starting at $T_i = 300$ K. If there is 1 kilomole of gas, by what amount ΔU did the internal energy of the gas change?

• A gas consists of atoms of mass 4×10^{-26} kg. If the gas is at 300 K, what is the average KE of a single atom?

If this gas has a pressure of 10^6 J/m^3 and volume of 0.01 m^3 what is its total internal energy U?

How many kilomoles of gas are there?

How many atoms of gas are there?