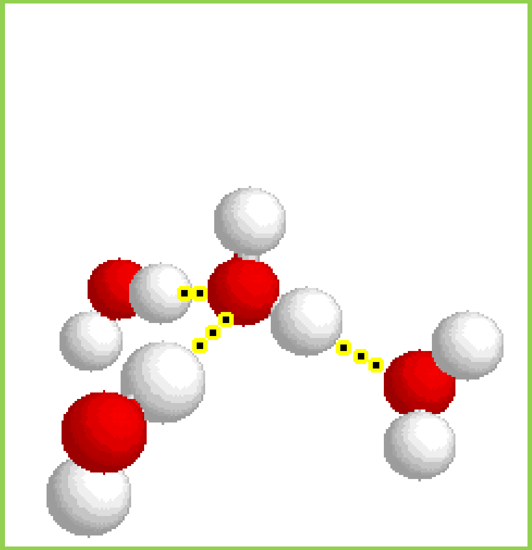
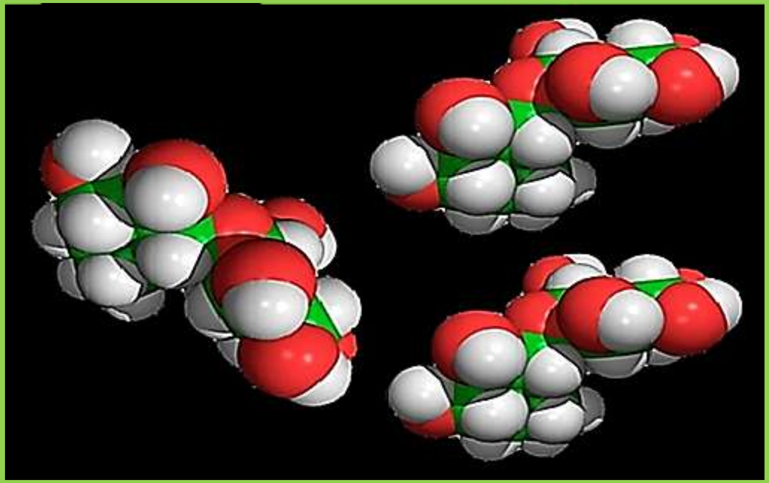
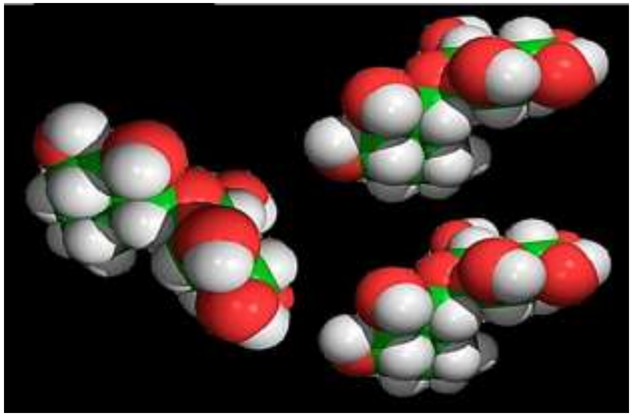
 

MOLECULES
TEMPERATURE

MOLECULES

Matter can be described as any object that occupies space and has weight and mass. It is always found in one of three states – solid, liquid or gas, but no matter which state it is in, matter is made up of microscopic particles called atoms. An atom is particle that is the most basic unit of matter. Any substance, whether solid, liquid or gas is made up of million of these tiny particles.
Molecules are made of two or more atoms (picture 1) joined together (the atoms are joined with chemical bonds- force of attraction between two atoms). They always posses the properties of matter.



Picture 1

MASS AND SIZE OF MOLECULES

Since atoms and molecules are very small in size, their masses are very small and determining their masses is very difficult. Atomic mass (atomic weight) is the mass of an atom in atomic mass unit (u), so a convenient unit to use is atomic mass unit (u).

1(atomic mass unit) $u = 1,66 \cdot 10^{-27} kg.$

The reason of using atomic mass unit is because the true mass of any atom is too small a number (on the order of $10^{-23} g$ for example, proton mass=$1{,}67x10^{-24} g$) to express in normall mass unit such as gram.

One atomic mass unit is defined as a mass exactly equal to $1/12$ the mass of one carbon- 12 (C^{12}) atom. A carbon- 12 atom has a relative mass of 12u (atomic mass unit) .

AMOUNT OF A SUPSTANCE. MOLAR MASS

The physical quantity that is determined by the number of molecules is called the amount of the substance. The **mole** is the SI unit for the amount of a substance that contains as many particles (atoms, molecules, etc.) as there are in 12 g of carbon-12. The mole is a basic unit of the SI system with the unit symbol **mol** . Multiple and submultiple units are also used such as the kilomole (kmol), the millimole (mmol) and the micromole (μmol).

The number of particles (atoms, molecules, etc.) contained in a mole of a substance is called the **Avogadro constant**. It was found experimentally that the Avogadro constant is: $\boldsymbol{N_A = 6,023 \cdot 10^{23} mol^{-1}}$

The molar mass of a supstance (M) is defined as the mass of one mole of that substance, usually expressed in grams per mole.

The amount of a substance (the number of moles of a supstance) can thus be found by dividing the mass of the substance by the molecular mass of substance

- $\boldsymbol{n_m = \frac{m}{M}}$

The amount of a substance (the number of moles of a supstance) can thus be found by dividing the number of the molecules by the Avogadro constant.

- $\boldsymbol{n_m = \frac{N}{N_A}}$

The molar volume, symbol $\boldsymbol{V_m}$ is the volume occupied by one mole of a substance (chemical element or chemical compound) at a given temperature and pressure. It is equal to the molar mass (M) divided by the mass density (ρ):

- $V_m = \frac{M}{\rho}$

The molar volume of any gas at standard pressure and standard temperature is 0,224 cubic decimetres per mole.

MOTION OF MOLECULES.TEMPERATURE AND KINETIC ENERGY

All matter is made of particles (atoms or molecules) that are in constant motion. Because the particles are in motion, they have kinetic energy. The faster the particles are moving, the more kinetic energy they have.

Picture 2
The gas particles on the right have more kinetic energy than those on the left. So, the gas on the right is at a higher temperature.

Well, as described in picture 2, the more kinetic energy the particles of an object have, the higher is the temperature of the object. Particles of matter are constantly moving, but they don't all move at the same speed and in the same direction all the time. As we can see in picture 2, the motion of the particles is random. The particles of matter in an object move in different directions, and some particles move faster than others. As a result, some particles have more kinetic energy than others. So what determines gas temperature?. When we measure temperature of gas , we measure the average kinetic energy of the particle in the gas.

The average value of the kinetic energy of translation motion of molecules is given by:

$$\overline{E_k} = \frac{E_{k1} + E_{k2} + \cdots + E_{kN}}{N}$$

$$\overline{E_k} = \frac{\frac{m}{2}({v_1}^2 + {v_2}^2 + \cdots + {v_n}^2)}{N}$$

$$\overline{v^2} = \frac{{v_1}^2 + {v_2}^2 + \cdots + {v_n}^2}{N}$$

where $v_1, v_2, \ldots v_n$ are velocities of molecules,
N is number of molecules and $\overline{v^2}$ is average value of square of the velocity of the molecules

Using last equation the average value of the kinetic energy of translation of molecules is given by: $\bar{E}_k = \frac{m\overline{v^2}}{2}$

Representing $\bar{v}^2$ in the form of the sum of the squares of the velocity components, we can write:

$$\overline{v^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2}$$

Owing to all the directions of motion having equal rights, the following equation is obeyed:

$$\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$$

- $\overline{v_x^2} = \frac{1}{3}\overline{v^2}$

Using last equation the average value of the kinetic energy of translation of molecules is given by:

- $\bar{E}_k = \frac{3m\overline{v_x^2}}{2}$

Since the average value of the square of velocity of molecules (along x-axes) is directly proportional to the apsolute temperature and inversly proportional to the mass of the molecules and proportional constant is the Boltzmann's constant

$k = 1{,}38 \cdot 10^{-23}$ J/K :

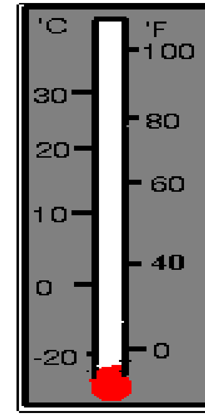
- $\bar{E}_k = \frac{3kT}{2}$

Conclusion:Temperature is a measure of the average kinetic energy of the translation motion of molecules.

The average kinetic energies of molecules of any gas at the same temperature are equal (the identity of the gas does not matter).

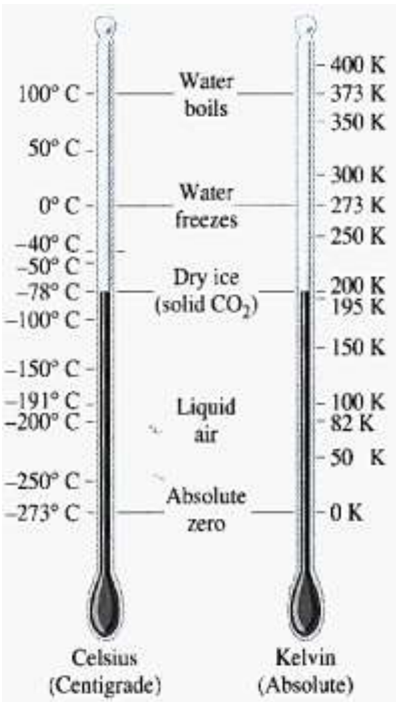
The temperature defined in this way is called the absolute temperature.
The SI unit of temperature is Kelvin.

THERMOMETER AND TEMPERATURE SCALES



picture 5

A thermometer is a device used for measuring temperature.
A liquid, usually alcohol or mercury is sealed in a glass tube (picture 5). When its heated, it expands rising higher in the tube. When it cools, it contracts, filling less of the tube.



Three temperature scales are in common use:

The Celsius temperature scale is based on the properties of water. It takes two fixed points, the melting point of pure ice and the boiling point of pure water, and divides the range between them into 100 equal intervals. On this scale, melting ice has a temperature of 0 ºC, and boiling water has a temperature of 100 ºC.

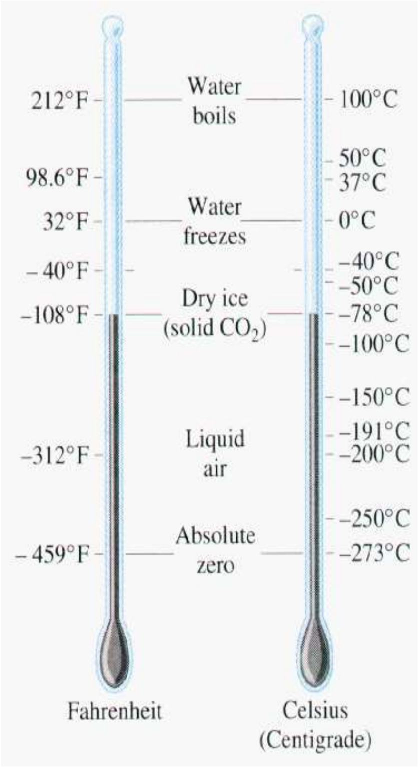
The Kelvin temperature scale is similar to the Celsius temperature scale in the sense that there are 100 equal degree increments between the normal freezing point and the normal boiling point of water. However, the zero-degree mark on the Kelvin temperature scale is 273.15 units cooler than it is on the Celsius scale. So a temperature of 0 Kelvin is equivalent to a temperature of -273.15 °C. Observe that the degree symbol is not used with this system. So a temperature of 300 units above 0 Kelvin is referred to as 300 Kelvin and not 300 degree Kelvin; such a temperature is abbreviated as 300 K.

Conversions between Celsius temperatures and Kelvin temperatures (and vice versa) can be performed using one of the two equations below

$$T(K) = t(°C) + 273{,}15$$

$$t(°C) = T(K) - 273{,}15^{\circ}$$

The most common temperature scale in use in the United States is the **Fahrenheit temperature scale**. The difference is that the normal freezing point of water is designated as 32 degrees and the normal boiling point of water is designated as 212 degrees in the Fahrenheit scale. As such, there are 180 divisions or intervals between these two temperatures when using the Fahrenheit scale. A temperature of 76 degree Fahrenheit is abbreviated as 76°F.



Temperatures expressed by the Fahrenheit scale can be converted to the Celsius scale equivalent using the equation below: $t(°\mathrm{C}) = \left(t(°\mathrm{F}) - 32^{°}\right)/1{,}8$

Similarly, temperatures expressed by the Celsius scale can be converted to the Fahrenheit scale equivalent using the equation below: $t(°\mathrm{F}) = 1{,}8 \cdot t(°\mathrm{C}) + 32^{°}$

Absolute zero is the lowest temperature possible. At a temperature of absolute zero there is no motion and no heat. Absolute zero occurs at a temperature of 0 degrees Kelvin, or -273.15 degrees Celsius, or at -460 degrees Fahrenheit.

In Superconducting state, the superconducting material shows the zero electric resistance (infinite conductivity). When the sample of a superconducting material is cooled below its critical temperature, its resistance reduces suddenly to zero. For example mercury shows zero resistance below 4k.