Medical Physics

The First Stage

Second Term – Third Lecture

2023 - 2024

Dr: Mahmoud Abdelhafez Kenawy

Continue with Thermodynamic Difination

State of System

In thermodynamics, a thermodynamic state of a system is its condition at a specific time; that is, fully identified by values of a suitable set of parameters known as state variables, state parameters or thermodynamic variables.

A thermodynamic system, delimited from the surroundings by real or hypothetical boundaries, can either be (1) isolated, (2) adiabatic, (3) closed, or (4) open, depending on the type of exchange between the system under consideration and the surroundings.

A system is defined as isolated in the absence of any exchange of energy or matter with the surroundings, adiabatic if only work is exchanged, closed if only energy is exchanged, and open if both energy and matter can be exchanged.

The state of a thermodynamic system is defined by its internal energy, U, and entropy, S, as well as a set of state variables, including temperature T, hydrostatic pressure P, volume V, and number of moles of components n.

System Properties

The system might typically be a certain mass of gas, or a mixture of liquid and gas (such as water and steam) or in solid state. The condition of the system is identified by a number of properties of state such as the temperature, pressure, and volume. The measurable quantities of a system are called state variables or properties of the system, and these quantities determine the state of the system.

There are dependent variable for the system such as mass of the system or its volume $(V = \frac{m}{\rho}; were\ m\ is\ mass, v\ is\ volum, \rho\ is\ density)$ or total system energy ($E_{tot} = E_K + E_p$; were E_K kinetic energy and Ep is potential energy); also there are independent variables such as tempreture or pressure.

Properties are sometimes divided into two types:

1. Extensive properties which depend on the mass of substance present, for example volume. The greater the mass of air, the greater will be the volume.

2. Intensive properties which do not depend on the mass of substance present, for example pressure and temperature. Specific volume is defined as the volume per unit mass, and so must be an intensive property.

Extensive properties are usually given an upper case symbol, for example V for volume. Intensive properties are usually given a lower case symbol, so p for pressure, and v for specific volume. However the use of T for the intensive property temperature is an exception to this rule.

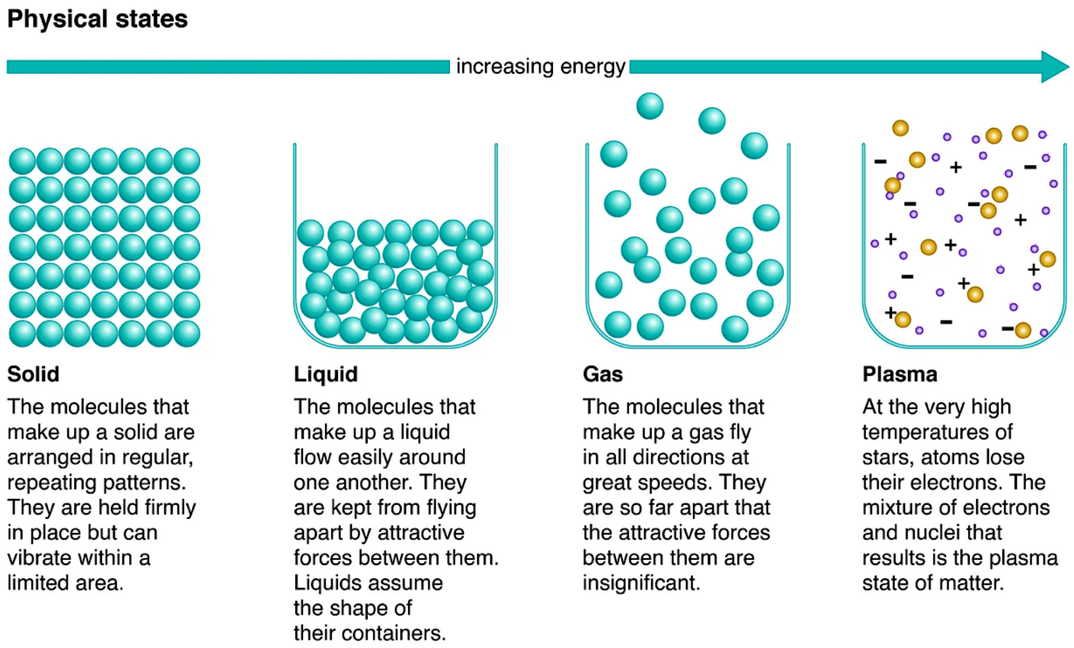
The matter

Matter is a substance made up of various types of particles that occupies physical space and has inertia. According to the principles of modern physics, the various types of particles each have a specific mass and size; (so matter consider type of system).

Matter incloudes atoms, molecules, elements and compounds.

States of matter

A state of matter is one of the distinct forms that different phases of matter take on. Four states of matter are observable in everyday life: solid, liquid, gas, and plasma; which also know as kinds of matter.



Equilibrium State in Physics

The word *equilibrium* implies a state of balance.

An object is in equilibrium in a reference coordinate system when all external forces (including moments) acting on it are balanced. This means that the net result of all the external forces and moments acting on this object is zero.

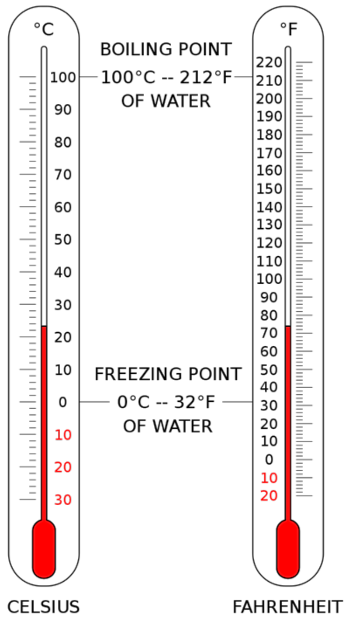
The systematic study of transformations of matter and energy in systems in terms of a concept called ***thermodynamic equilibrium***.

For two sysems, the equilibrium state when the two sytem have same propartis and same state mesurements.

Temperature

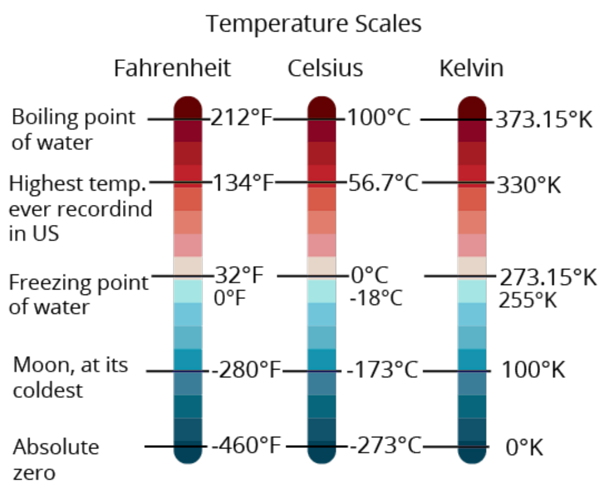
Temperature is a physical quantity that quantitatively expresses the attribute of hotness or coldness. Temperature is measured with a thermometer. It reflects the average kinetic energy of the vibrating and colliding atoms making up a substance.

By other definition, it is representing the average kinetic energy of the particles in a system. It's a measure of how hot or cold a system.



<u>Thermometers</u> are calibrated in various temperature scales that historically have relied on various reference points and thermometric substances for definition. The most common scales are the *Celsius scale* with the unit symbol °C (formerly called centigrade), the *Fahrenheit scale* (°F), and the *Kelvin scale* (K), the latter being used predominantly for scientific purposes.

The kelvin is one of the seven base units in the International System of Units (SI). Absolute zero, i.e., zero kelvin or −273.15 °C, is the lowest point in the thermodynamic temperature scale.



Experimentally, it can be approached very closely but not actually reached, as recognized in the third law of thermodynamics. It would be impossible to extract energy as heat from a body at that temperature.

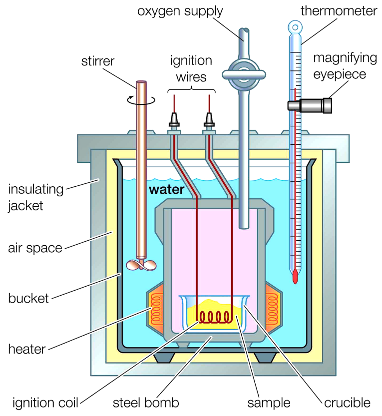
Temperature is important in all fields of natural science, including physics, chemistry, Earth science, astronomy, medicine, biology, ecology, material science, metallurgy, mechanical engineering and geography as well as most aspects of daily life.

The Heat

In thermodynamics, *heat* is the thermal energy transferred between systems due to a temperature difference. In colloquial use, heat sometimes refers to thermal energy itself. Thermal energy is the kinetic energy of vibrating and colliding atoms in a substance.

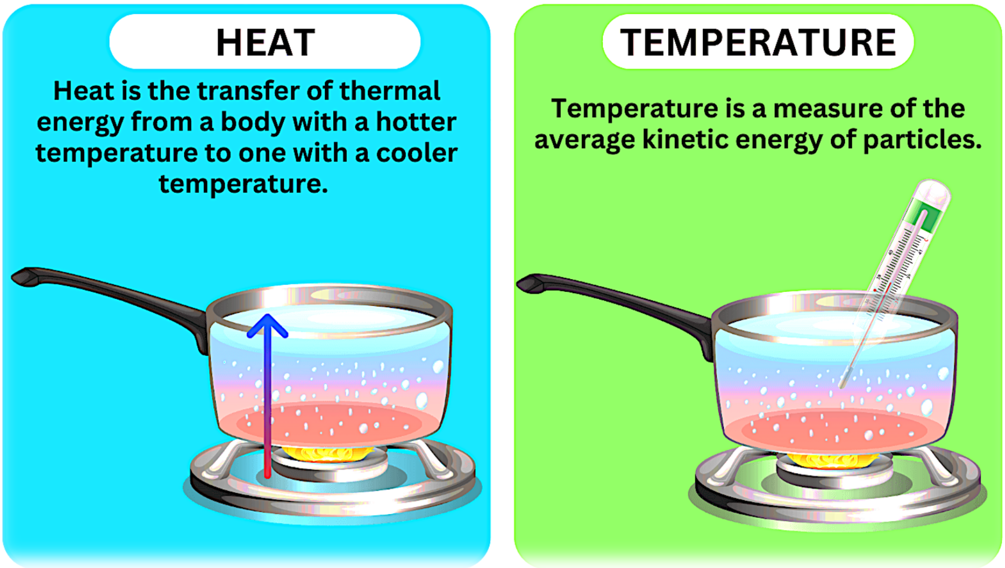
Heat is energy in transfer to or from a thermodynamic system by a mechanism that involves the microscopic atomic modes of motion or the corresponding macroscopic properties. This descriptive characterization excludes the transfers of energy by thermodynamic work or mass transfer. Defined quantitatively, the heat involved in a process is the difference in internal energy between the final and initial states of a system, and subtracting the work done in the process. This is the formulation of the first law of thermodynamics.

Calorimetry is measurement of quantity of energy transferred as heat by its effect on the states of interacting bodies, for example, by the amount of ice melted or by change in temperature of a body.



In the International System of Units (SI), the unit of measurement for heat, as a form of energy, is the joule (J).

Heat vs Temperature



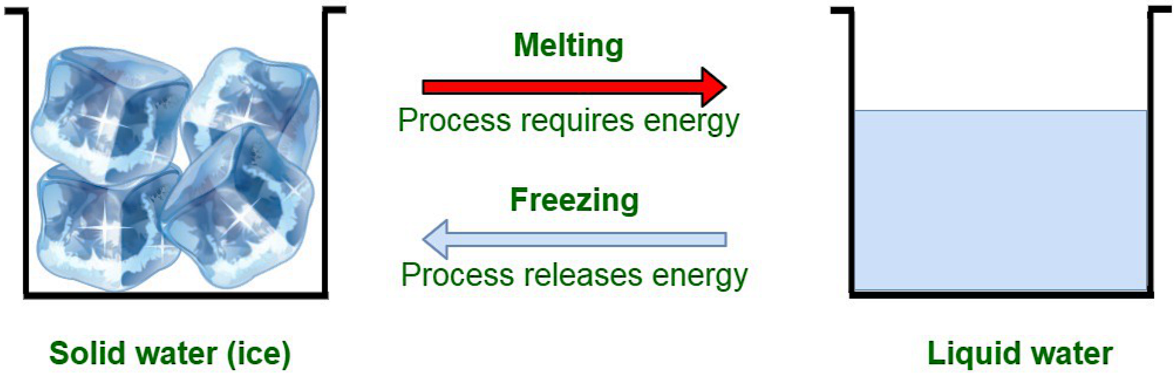
<u>Spontaneous and Non-Spontaneous Processes</u>

In chemical science *<u>spontaneous reactions</u>* are those chemical or biological reactions that take place without the influence of external factors, while *<u>non-spontaneous reactions</u>* are those chemical reactions that require an energy input to proceed or that cannot take place without the influence of external factors.

A spontaneous process is one that occurs naturally under certain conditions.

A nonspontaneous process, on the other hand, will not take place unless it is "driven" by the continual input of energy from an external source.

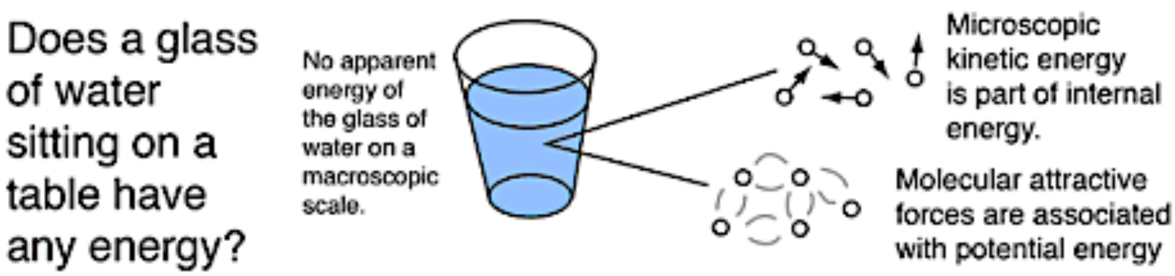
At room temperature and typical atmospheric pressure, for example, ice will spontaneously melt, but water will not spontaneously freeze.



Internal Energy

The internal energy of a thermodynamic system is the energy contained within it, measured as the quantity of energy necessary to bring the system from its standard internal state to its present internal state of interest, accounting for the gains and losses of energy due to changes in its internal state, including such quantities as magnetization.

By other simple words, ***internal energy*** is defined as the energy associated with the random, disordered motion of molecules. It is separated in scale from the macroscopic ordered energy associated with moving objects; it refers to the invisible microscopic energy on the atomic and molecular scale.



The symbol **U** is used for the internal energy and the unit of measurement is the joules (J).

Internal energy increases with rising temperature and with changes of state or phase from solid to liquid and liquid to gas.

The Pressure

Pressure is force per unit area. (P=F/A)

The symbol **P** is used for the pressure and the unit of measurement is Pascal (Pa) or newton per square meter (N/m^2).

The work

In physics, ***work*** is the energy transferred to or from an object via the application of force along a displacement.

A force is said to do *positive work* if when applied it has a component in the direction of the displacement of the point of application. A force does *negative work* if it has a component opposite to the direction of the displacement at the point of application of the force.

The symbol **W** is used for the work and the unit of measurement is the joules (J). The mathematical expression for work depends upon the particular circumstances. Work done in compressing a gas at constant temperature may be expressed as the product of pressure P times the change in volume dV; that is, $W = PdV$.

Volume (V): refers to the space occupied by the system.

Composition: defines the amount of each component present for systems with more than one component (e.g., mixtures).

Thermodynamic Processes

1- An *isothermal process*, during which the system's temperature remains constant.

2- An *adiabatic process*, during which no heat is transferred to or from the system.
3- An *isobaric process*, during which the system's pressure does not change.
4- An *isochoric process*, during which the system's volume does not change.

.... and it will discuss in details in next lecture.

Thermal Equilibrium

What does thermal equilibrium mean?

Two objects are at thermal equilibrium when there is no net energy transfer between them. Objects at thermal equilibrium with each other are at the same temperature and can exchange energy between them. Objects in contact have a tendency to move toward thermal equilibrium.

What is an example of thermal equilibrium?

Hot tea left on the counter illustrates thermal equilibrium and the tendency of objects in thermal contact to move towards equilibrium. As air molecules and water molecules collide on the surface of the tea, heat is transferred from the tea to the surrounding air. The result is that the tea cools to room temperature and the air is heated slightly.

What happens at thermal equilibrium?

When objects are at thermal equilibrium, there is no net exchange of kinetic energy between them. Molecules may randomly collide and transfer kinetic energy to each other, but on average, the kinetic energy of both systems is equal and constant.

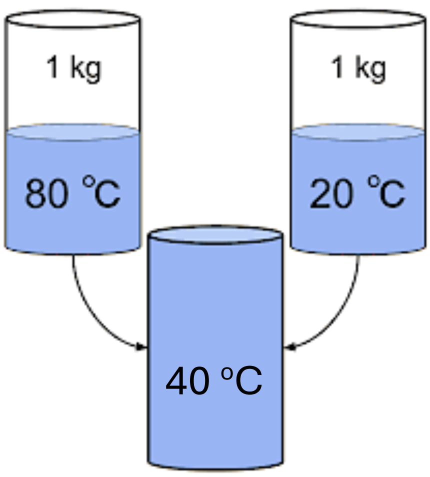
Temperature and Zeroth Low of Thermodynamic

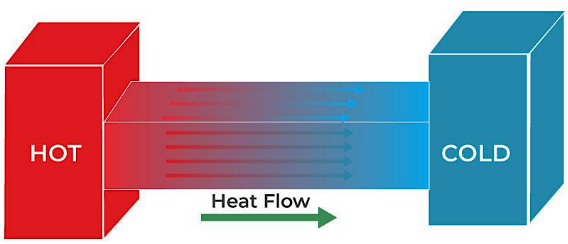
We often associate the concept of temperature with how hot or cold an object feels when we touch it. In this way, our senses provide us with a qualitative indication of temperature. Our senses, however, are unreliable and often mislead us.

For example, if you stand in bare feet with one foot on carpet and the other on an adjacent tile floor, the tile feels colder than the carpet even though both are at the same temperature. The two objects feel different because tile transfers energy by heat at a higher rate than carpet does. Your skin "measures" the rate of energy transfer by heat rather than the actual temperature. What we need is a reliable and reproducible method for measuring the relative hotness or coldness of objects rather than the rate of energy transfer. Scientists have developed a variety of thermometers for making such quantitative measurements.

If you have two objects at different initial temperatures eventually reach some intermediate temperature when placed in contact with each other.

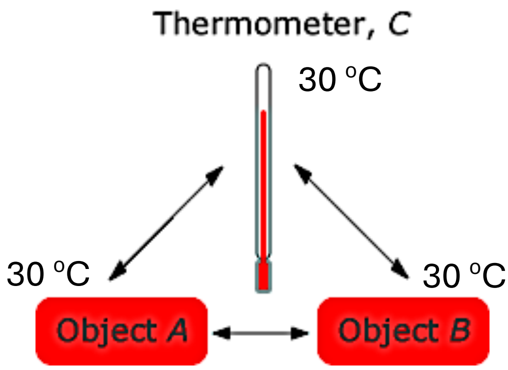
For example, when hot water and cold water are mixed in a container, energy is transferred from the hot water to the cold water and the final temperature of the mixture is somewhere between the initial hot and cold temperatures.





Imagine that two objects are placed in an insulated container such that they interact with each other but not with the environment. If the objects are at different temperatures, energy is transferred between them, even if they are initially not in physical contact with each other.

For purposes of this discussion, let's assume two objects are in thermal contact with each other if energy can be exchanged between them by these processes due to a temperature difference. Thermal equilibrium is a situation in which two objects would not exchange energy by heat or electromagnetic radiation if they were placed in thermal contact.

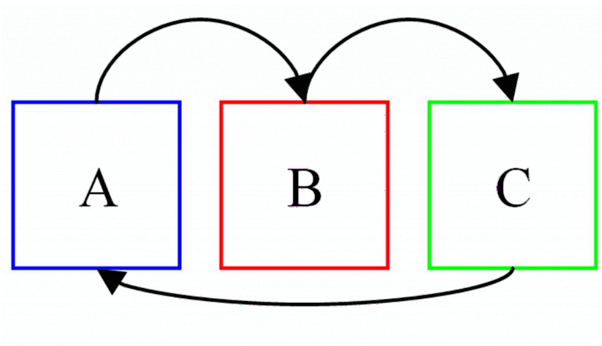


Let's consider two objects A and B, which are not in thermal contact, and a third object C, which is our thermometer. We wish to determine whether A and B are in thermal equilibrium with each other. The thermometer (object C) is first placed in thermal contact with object A until thermal equilibrium is reached as shown in last Figure.

From that moment on, the thermometer's reading remains constant and we record this reading. The thermometer is then removed from object A and placed in thermal contact with object B as shown in last Figure. The reading is again recorded after thermal equilibrium is reached. If the two readings are the same, we can conclude that object A and object B are in thermal equilibrium with each other. If they are placed in contact with each other, there is no exchange of energy between them.

We can summarize these results in a statement known as the zeroth law of thermodynamics (the law of equilibrium):

> If objects A and B are separately in thermal equilibrium with a third object C, then A and B are in thermal equilibrium with each other.



Quick Quiz:

(Q1) Two objects, with different sizes, masses, and temperatures, are placed in thermal contact. In which direction does the energy travel?

(a) Energy travels from the larger object to the smaller object.

(b) Energy travels from the object with more mass to the one with less mass.

(c) Energy travels from the object at higher temperature to the object at lower temperature.

(Q2) What is the meaning of the following:

1- Pressure.

2- Temperature and heat energy and what is the difference between them.

3- System, system properties, system states and system thermal equilibrium.

4- Total system energy.

5- System internal energy and kinetic energy.

6- Work done in thermal system.

7- Different types of thermal processes.

8- Spontaneous and Non-Spontaneous Processes.

(Q3) How you can measure system temperature and heat energy; describe the devices and they units.

(Q4) What is the statement of the law of equilibrium in thermodynamic? explain your answer with an example.