Chapter Two

1- Temperature

Is a physical quantity expressing the subjective perceptions of hot and cold. Temperature is measured with a thermometer. Historically calibrated in various temperature scales and units of measurement. The most commonly used scales are the Celsius scale, denoted in °C (informally, degrees centigrade), the Fahrenheit scale (°F), and the Kelvin scale. The kelvin (K) is the unit of temperature in the International System of Units (SI). The lowest theoretical temperature is absolute zero. Absolute zero is denoted as 0 K on the Kelvin scale, −273.15 °C on the Celsius scale. Heat is the amount of energy that flows spontaneously from a warmer body to a cooler one because of different in temperature. The **zeroth law** of thermodynamics states that (if two bodies A and B are each in thermal equilibrium with third body C the thermometry then A and B are in thermal equilibrium with each other).

2- Kind of thermometers

A thermometer is a device that measures temperature or temperature gradient, using a variety of different principles.

1-The gas thermometer: The thermometric property is the pressure of a constant volume.

2-Electric resistance thermometer: The thermometric property is the electric resistance for small coil of wire.

3-Thermocouple: The thermometric property is the electromotive force.

In thermodynamics, the triple point of a water at which the three phases (gas, liquid, and solid) of that substance coexist in thermodynamic equilibrium. The single combination of pressure and temperature at which liquid water, solid ice, and water vapor can coexist in a stable equilibrium occurs at exactly 273.16 K .The triple point of water is used to define the kelvin, the base unit of thermodynamic temperature in the International System of Units (the triple point of water (273.16 K). Triple point the pressure is P_{tp}. And P the pressure at the point in the question. Then to calculate temperature we write as:

$$T_K = 273.16 * \frac{P}{P_{tp}} \qquad K^0$$

So for we have defined the Kelvin scale (T_K) for any gas. We have another temperature scale is in common use the Celsius scale defined

$$T_{C^\circ} = T - 273.15$$

3- Heat and the first law of thermodynamics

Energy transfer between system and surrounding is

1. Heat Q: energy transferred because of a temperature difference.

2. Work W: energy produced through an additional force, such as mechanical work,

$$Q + W = \Delta E \quad ....(1)$$

$$\Delta E = E_2 - E_1$$

WhereΔE is internal energy equation (1) is called the first law of thermodynamic ((the change in internal energyΔE of a system is equal to the heat added to the system plus the work done by system))

quantity Q +W depends only on the initial and the final state.

Heat energy transferred by **Conduction**, **convection** and **radiation.**

4-Heat Capacity

The heat capacity, of a system is the ratio of the heat added to the system to the resultant change in the temperature.

Heat capacity = Q/ ΔT

Suppose M is mass for this system, then the heat capacity per unit mass is called the **specific heat capacity** we shall denoted by the letter C

$C = \frac{heat\ capacity}{mass} = \frac{Q}{m\Delta T}$

The specific heat can be measured under conditions of constant pressure C_p or constant volume C_V. Also we can express the heat capacity by a number of moles change of mass. Where n is number of moles.

(n = m / M) where m is mass M is atomic mass. We know that the express to one gram molecular or gram atomic. Mole contains of constant number of particles this called constant or number avogadro (N_O) equal.

$N_O = 6.0249*10^{23}\ mol^{-1}$

n = m / M

m = NM

$$C = \frac{Q}{nM\Delta T}$$

$$CM = \frac{Q}{n\Delta T}$$

The quantity CM is called molar heat capacity and denoted by C this mean

$$C = \frac{Q}{n\Delta T}$$

$$Q = Cn\,\Delta T$$

$$Q = Mc\Delta T = Cn\Delta T$$

The unit of specific heat is ($J\ gm^{-1}\ deg^{-1}$). The unit of molar heat capacity is ($J\ mol^{-1}\ deg^{-1}$). The unit of heat is joul. And we have another unit is called **Calarie.**

1 Cal =4.186 J

1KCal = 4186 J

Where Kcal is kilogram – calorie

They find that specific heat for sold material is decrease when the temperature is decrease and reached to zero when approach the temperature to zero kelvin.

4-Latent Heat

Is thermal energy released or absorbed, by a body or a thermodynamic system, during a constant-temperature process. Latent heat″ is internal energy concerning the phase (solid / liquid / gas) of a material. Changes of Latent heat is associated with the change of phase of atmospheric water, vaporization and condensation, Two common forms of latent heat the first latent heat of fusion (melting) denoted by (l_f) that must be change from solid to liquid under condition of a constant-temperature and pressure the second latent heat of vaporization (boiling) denoted (l_v) that must be change from liquid to gas . Sublimation refers to state from the solid to the gas. .These names describe the direction of energy flow when changing from one phase to the next and depends not only **the latent heat** but also on **the total mass** of substance.

$$Q = m\,l$$

Where (l) is latent heat, (m) is mass of substance and Q is heat required

5-Transfer of Heat

When two bodies are at different temperatures, thermal energy transfers from the one with higher temperature to the one with lower temperature. Heat always transfers from hot to cold. There are three modes of heat transfer: conduction, convection, and radiation.

1- Conduction

Conduction is at transfer through solids or stationery fluids. When you touch a hot object, the heat you feel is transferred through your skin by conduction. The direction of heat flow is always from points of higher to point of lower. This method depend

1- Cross-sectional area through which the heat is conducting.

2- Difference temperature between the two surfaces.

3- Distance separated between the centers of two surfaces.

4-Constant proportion called the thermal conductivity of material.

Let (H) represent the quantity of heat flowing through the slice Per unit time and is called heat current. And (K) is called the coefficient of thermal conductivity. A is the cross-sectional area of the material and

$\frac{\Delta T}{\Delta X}$

Is the temperature gradient (the average changes of temperature with the distance X at any point and tie interval).

$$\frac{\Delta Q}{\Delta t} = -KA\frac{\Delta T}{\Delta X}$$

Or

$$H = -KA\frac{\Delta T}{\Delta X}$$

This is called Fourier law when K is large conduct heat then the material said to be good conductor, and it K small conduct heat then the material said to be poor conductor.

2-Transfer of heat by convection

In convective heat transfer, the bulk fluid motion of the fluid plays a major role in the overall energy transfer process. It is mean that the transfer of heat from one place to another by actual motion of hot material (fluid). It is deepens on many things such as:

1-Whether the surface is flat or curved.

2-Whether the surface is horizontal or vertical.

3-Whether the fluid is contact with the surface is a gas or liquid.

4- The density, viscosity, specific heat and thermal conductivity of the fluid.

5-Whether the velocity of the fluid is small enough rise to laminar flow or large enough to cause turbulent flow.

3-Transfer of heat by radiation

Radiation has come to mean a flow of energy through some medium, possibly vacuum. In a classical view, the energy can be carried by both particles (α and β particle radiation, etc.) and by waves (acoustic radiation, electromagnetic radiation, etc.). This energy is called radiation energy it is transmitted with speed of light and its transfer by electromagnetic waves such as from the sun. The body is a good absorber is also emitter. The body which absorbs all the radiation that fall on is called **Black Body**. The types of emissivity of objects comparatively with emission of black body.

The emission power = emissivity

Is defined (it is the total emission energy of all wave lengths from emission object for each square meter of surface at one second). And the emissivity of black body denoted by $\varepsilon_\circ$ which proportion with the fourth power of kelvin temperature.

$$\varepsilon_\circ \propto T^4$$

Where T kelvin temperature and constant proportion called **Stafon constant** denoted by where $\varepsilon_\circ = \sigma \ T^4$

This is called Stafan – Boltzman Law also can write the last equation for not block body as $\varepsilon = e\varepsilon_\circ = e\sigma T^4$

Where ε is total emissivity of any object and (e) is emissivity and depends on the nature of surface emission and is number between (0) and (1) (1 > e > 0), for black body is equal one (1). The value of e depends somewhat on the temperature of the body for example if (T) is the temperature of body and put in vessel which temperature is (T_0) such as (T_0 < T). Then there is flow thermal radiation for unit area for each second is equal.

$$e\sigma T^4 - e\sigma T_\circ^4 = e\sigma\left(T^4 - T_\circ^4\right)$$

Notice that the radiation from body is occur if there is different temperature between the body and surrounding.

Example (1)

1- How much heat is required to convert (5gm) of ice at ($-5C^0$) to water at ($50C^0$) where specific heat of ice is (2.11 J/gm deg) and specific heat of water is (4.86 J/gm deg) and latent heat of fusion is (334.8 J/gm).

Solution

We can determine the convert such as :

Ice at ($-5C^0$) Q_1 ice at ($0C^0$) Q_2 ice to water Q_3 raise water to ($50C^0$)

The total heat required Q is added of quantities of heat

$Q= Q_1 +Q_2 +Q_3$

$Q1 = mc (Q_2 - Q_1)$

$= 5*2.11 (0 - (-5)) = 53J$

$Q2= ml_f = 5 *334.8 = 1674$ J

$Q3= mc (Q_2 – Q_1) + 5* 4.186 *(50 – 0) = 1046$ J

Q = 53 +1674 + 1046 = 2773 J

Example (2)

How much energy does a refrigerator have to remove from (1.5 kg) of water at ($20C^0$) to make ice at ($-12C^0$) where specific heat of ice (2.11J gm^{-1} deg^{-1}) and specific heat of water is (4.186 J gm^{-1} deg^{-1}) and latent heat of fusion is (334.8 J gm^{-1}).

Solution

Heat must flow out to reduce the water from ($20C^0$) to ($0C^0$) change it to ice, and then to lower the ice from ($0C^0$) to ($-12C^0$)

$Q = mc\,(20 - 0) + ml_f + mc\,(0 - (-12))$

$= 1.5 * 4186 * 20 + 1.5 * 3.348 * 10^5 + 1.5 * 2110 * 12 = 6.6 * 10^5$ J =660 KJ

Example (3)

100 Piece of copper each mass at it is (3gm) and is pieces in water hot and leaving it until will be equilibrium temperature water then placed in water cool at ($20C^0$) and it mass is (200 gm). What is the final temperature of water and pieces of copper where specific heat of water is ($4.186\ J\ gm^{-1}\ deg^{-1}$) and specific heat of copper is ($0.39\ J\ gm^{-1}\ deg^{-1}$).

Solution

Heat lost by pieces of copper (Q_1) = Heat gained by water (Q_2)

$Q_1 = mc\,(100 - Q_f)$ where boiling temperature of water ($100\ C^0$)

$= 3*100 * 0.39 * (100 - Q_f) = 300 * 39 - 3 * 39\, Q_f$

$= 11700 - 117\, Q_f$

$Q2 = 200*4.186\,(Q_f - 20) = 2*418.6\, Q_f - 4*4186 = 837.2\, Q_f - 16744$

$Q1 = Q2$

$= 11700 - 117\, Q_f - 837.2\, Q_f - 16744$

$Q_f = 28444 = 29.8\ C0$