# Joule's Law of Heating, Thermoelectricity and Chemical Effect of Current

## Joule's Law of Heating

When a current is passed through a conductor, the conductor gets heated. This phenomena is called joule's heating effect.

If $V$ is in volt, $i$ in amp, $R$ in Ohm then joules heat is equivalent to:

$$\mathrm{W} = \mathrm{Vit} = \mathrm{i}^2\mathrm{Rt} = \frac{V^2 t}{R}\ \mathrm{J}$$

In calorie,

$$\text{heat produced } (\mathrm{H}) = \frac{W}{J} = \frac{Vit}{J} = \frac{i^2 Rt}{J}$$

Where $\mathrm{J} = 4.18 \times 10^3\ \mathrm{J/kilocal}$

## Power

The rate of work done is called the power and energy is dissipated in the form of heat.

$$P = \frac{dw}{dt} = Vi = i^2 R = \frac{V^2}{R}$$

The unit of power is watt.

## Electrical energy

The usual unit of energy is Joule but for convenience a large unit kilowatt hour (kwh) is used.

$$\begin{aligned} 1\mathrm{kwh} &= \mathrm{P}(\text{ in kilowatt }) \times (\mathrm{t} \text{ in hour }) \\ &= 1000 \times 3600 \text{ joule} \\ &= 3.6 \times 10^6 \mathrm{J} \end{aligned}$$

## Specification of a Bulb or other electric appliances

When a bulb is specified voltage $V$ and power $P$, then resistance $R$ and maximum allowed current may be determined.

$$\begin{aligned} \mathrm{Power\ (p)} &= \mathrm{V} \times \mathrm{i} \\ \text{or }, \mathrm{i} &= \frac{\mathrm{P}}{\mathrm{V}} \end{aligned}$$

Resistance of its filament

$$\mathrm{R} = \frac{V}{i} = \frac{V}{P/V} = \frac{V^2}{P}$$

The bulbs and other electric appliances are manufactured for paralled combination.

- The brightness of a bulb is directly proportional to the rate of production of heat of the bulb.
- The rated power of bulb is always inversely proportional to resistance.

  $$\therefore \mathrm{P} \propto \frac{1}{R} \text{ so}, \mathrm{R} \propto \frac{1}{P}$$

  $\therefore$ In series combination current is same
  $\therefore \mathrm{H} \propto \mathrm{R} \quad \left(\mathrm{H} = \mathrm{I}^2\mathrm{Rt}\right)$
- In parallel combination,

  $$\mathrm{H} \propto \frac{1}{R}\left[\mathrm{H} = \frac{V^2 t}{R}\right]$$
- For series combination,

$$\frac{L_1}{L_2} = \frac{H_1}{H_2} = \frac{R_1}{R_2} = \frac{P_2}{P_1}$$

Where $L$ is inensisty of glowing light.

- For parallel combination, $\mathrm{L} \propto \frac{1}{R} \propto \mathrm{P}$

Chemical effect of current

## Electrolysis

The process by which a liquid is decomposed into ions on passing electric current is called electrolysis the liquid which conduct electricity and undergoes decomposition is called the electrolyte.

## Faraday's laws of electrolysis

a. ### First law

The mass of ions liberated or deposited on each electrode is proportional to total charge passed through the electrolyte.
$i.e,\ m \propto q$
Or, $m \propto it$
Or, $m = zit \ldots\ldots (i)$

b. ### Second law

The mass of ions deposited on each electrode is proportional to chemical equivalent of ions i.e.
$m \propto w$

Thus if $m_1$ and $m_2$ are the masses of substances of chemical equivalents $w_1$ and $w_2$ respectively then

$$\frac{m_1}{m_2} = \frac{w_1}{w_2}$$

As $m = Zq$, So,

$$\frac{m_1}{m_2} = \frac{z_1}{z_2}\frac{q}{q} = \frac{z_1}{z_2}$$

$$\therefore \frac{m_1}{m_2} = \frac{z_1}{z_2} = \frac{w_1}{w_2}$$

## Faraday constant (F)

As we have $\frac{w}{z} = \text{constant}$

The ratio $\frac{w}{x}$ is called faraday's constant. It represents the amount of charge required to deposit or liberate one kilogram equivalent of any element.

$$\mathrm{F} = 9.65 \times 10^7 \mathrm{C}$$

Thermoelectricity

- ## Seebeck effect (Thermoelectric effect)

  When the junctions of two dissimilar metals are maintained at different temperatures, then e.m.f. is produced depending on the nature of metals. This effect is called Seeback effect.

  ### Seebeck series:

  Bi, Ni, Co, Pt, Cu, Mn, Hg, Ph, Sn, Au, Ag, Zn, Cd, Fe, As, Sb

  - The farther apart the metals are in the series, the greater is the emf produced. Therefore emf produced is maximum for Si – Sb thermocouple.
  - The direction of current is from earlier (Bi) to later (Sb) element across cold junction.
  - Induced emf in thermocouple is:

    $$E = a\theta + b\theta^2$$

where, $\theta$ is temperature of hot junction and temperature of cold junction is $0^o\ C$.

- At neutral temperature ( $\theta_n$ ), E is maximum and thermoelectric power $= 0$.
- At inversion temperature ( $\theta_i$ ), $E = 0$ and $\theta_i = 2\theta_n$

- ## Peltier effect

  Inverse of Seebeck effect is the peltier effect. It states that if an emf is applied in a thermo couple formed of two junction, one junction is heated and other is cooled.

- ## Thomson Effect

  When a temperature difference is maintained between different parts of same metal and a current is passed thorough it, heat is either absorbed or evolved along metal. This is called Thomson effect.