33. Thermal and Chemical effects of Electric Current

Short Answer

Answer.1

We know Joule's heating effect –

Joule's heating effect is the process by which the passage of an electric current through a conductor produces heat

When a constant potential difference is applied across a bulb, due to Joule's heating effect, the temperature of the bulb increases.

We know in case of metals, the temperature co-efficient is positive, which means, with increase in temperature, the Resistance of the metal increases.

In case of metals, the resistance and temperature is related as -

$$R = R_0(1 + \alpha\,(T - T_0).$$

Where,

R= resistance at some temperature T

R_0 = resistance at zero temperature

and α = Temperature co-efficient.

From ohm's law

Voltage, $V = I \times R$

Where

I is the current

R is the resistance

Thus, from the above formula, we get that with increase in resistance, current decreases. if the voltage remains constant

Now, the heat generated by the resistance is constantly radiated through the connecting wires into the surroundings.

Thus, the value of its temperature is maintained constant and so its resistance.

As a result, the current through the bulb filament becomes constant.

Answer.2

Given ∈ as emfs of the circuits with internal resistances r

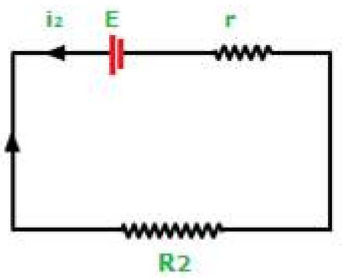
Let the currents passing through the

resistance R_1 and R_2 be i_1 and i_2 , respectively for time t.

According to Kirchhoff's Voltage Law, sum of

all voltages around any closed loop in a

circuit must equal zero.



ie, $\sum V_{net} = 0$

Looking into the circuit 1-we get-

$\in - i_1 r - i_1 R_1 = 0$

$\Rightarrow i_1 = \frac{\in}{r+R_1}$(1)

Similarly, the current in the other circuit,

$i_2 = \frac{\in}{r+R_2}$(2)

The heat lost through a resistor r is given by

$h = i^2 \times r \times t$ (3)

Now the total thermal energies through the resistances from Joule's heating effect are given

by -

$i_1^2 R_1 t = i_2^2 R_2 t$

From(1), (2) and (3)

$\Rightarrow (\frac{\epsilon}{r+R_1})^2 \times R_1 t = (\frac{\epsilon}{r+R_2})^2 \times R_2 t$

$\Rightarrow (\frac{1}{r+R_1})^2 \times R_1 = (\frac{1}{r+R_2})^2 \times R_2$

$\Rightarrow (\frac{1}{r+R_1})^2 \times R_1 = (\frac{1}{r+R_2})^2 \times R_2$

$$\Rightarrow \frac{(r^2 + R_1^2 + 2rR_1)}{R_1} = \frac{(r^2 + R_2^2 + 2rR_2)}{R_2}$$

$$\Rightarrow \frac{r^2}{R_1} + R_1 = \frac{r^2}{R_2} + R_2$$

$$\Rightarrow \ (R_2 - R_1) \ = +r^2 (\frac{1}{R_1} - \frac{1}{R_2})$$

$\Rightarrow r = R_1 R_2$

Hence, the condition when the thermal energies developed in

$R_1$and R_2 be equal in a given time is when the internal resistance r–

$\Rightarrow r = R_1 R_2$

Answer.3

We know that adiabatic process occurs without the transfer of heat or mass of substances between a thermodynamic system and its surroundings.

Now, in this case, No.

There is no exchange of heat with surrounding in case of adiabatic process.

In case of resistance,

Heat is developed by the virtue of Joule heating effect in the capacitor, which state that the heat developed in the resistance is given by

$H = i^2 RT$

Where,

I is the current in the circuit

R is the resistacne of thetemperature

T is the time perod for which current is allowed to transfer in the circuit.

The heat developed by the resistor led to increase in the operating temperature of the resistor due to which the resistance of the resistor increase with the increase of the resistance given by the formua below:

$$R = R_0(1 + \alpha (T - T_0).$$

Where,

R= resistance at some temperature T

R_0 = resistance at zero temperature

and α = Temperature co-efficient.

Thus, the heat generated is exchanged between the resistor and surrounding.

Thus, the above process cannot be an adiabatic process.

Answer.4

First law of thermodynamics states –

the total energy of an isolated system is constant, energy can neither created nor destroyed, but can be transformed from one form to another

$$\Delta U = \Delta Q - \Delta W$$

where

ΔU is the change in the internal energy,

ΔQ is the heat added to the system,

and ΔW is the work done by the system.

Now, here the battery is doing positive work on a resistor carrying current *i*.

Thus, ΔW is positive.

The work done on the resistor is used to increase its thermal energy in the form of heat, thus ΔQ is positive.

As the temperature of the resistor rises, ΔU is positive.

Answer.5

Thermocouples are of two wire legs made from different metals. These wires legs are welded together at one end, creating a junction.

This junction is where the temperature is measured.

When the change in temperature occurs at junction, a voltage is created.

Now neutral temperature for the thermocouple.is the temperature of the hot junction at which the thermo-emf in a thermocouple becomes maximum

For a thermocouple with constants a and b having the same sign, the neutral temperature will be less than the cold junction temperature of thermocouple, as

$$\theta n = -\frac{a}{b}$$

Hence there will be no neutral or inversion temperature, since the hot junction temperature cannot be less than the temperature of cold junction of thermocouple.

Answer.6

In thermocouple when, keeping the temperature of the cold junction constant, the temperature of the hot junction is gradually increased.

The thermodynamic emf rises to a maximum at a temperature (θ_n) called neutral temperature and then gradually decreases and eventually becomes zero at a particular temperature (θ_i) called temperature of inversion.

If, the inversion temperature and neutral temperature both measured in degree Celsius, then we can say "inversion temperature is always double the neutral temperature"

But if measured in other units such as Kelvin, inversion temperature may not be double the neutral temperature

Answer.7

No, the neutral cannot be the arithmetic mean of the inversion temperature and the temperature of the cold junction always.

Neutral temperature is defined as the temperature of the hot junction of a thermocouple attains its maximum value, when the clod junction is maintained at a constant temperature of $0^{o}C$.

While the inversion temperature is the critical temperature at which a non-ideal gas experiences a decrease in temperature will experience a temperature decrease and above which will experience a temperature increase.

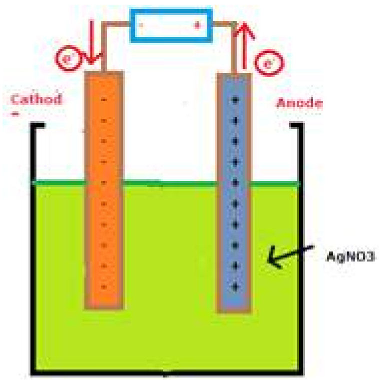
Neutral temperature does not change for a metal whether the temperature of cold junction and inversion temperature change by any value.

This is valid only Celsius is the unit for both the temperatures.

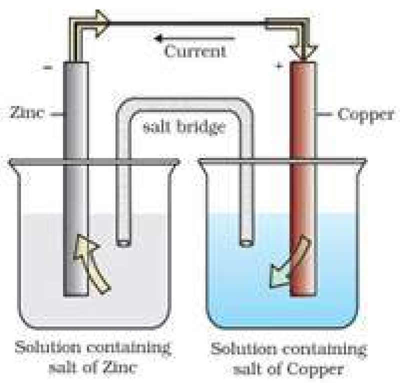
Answer.8

An electrolytic cell is an electrochemical cell that drives a non-spontaneous redox reaction through the application of electrical energy through the electrodes.

Now, the electrodes in an electrolytic cell cannot have fixed polarity like that of a battery.



Lets take an example of electrolytic cell as show below:



The redox reaction for the above cell is given as below:

Zn(S) +Cu^{2+} (aq) → Zn^{3+} (aq) + Cu(s)

The cell potential is 1.1 eV

If external potential less than 1.1 eV is applied to the cell the electron flow from Zn rod to Cu rod hence current flows from Cu to Zn. Zinc rod will act as Cathode while the copper rod will act as Anode.

If the external potential is greater than 1.1V. Electrons flow from Cu to Zn and current flows from Zn to Cu. The Zinc rod act as anode while copper rod acts as cathode.

Thus, we an infer that the electrodes of the electrolytic cell cannot have fixed polarity.

Answer.9

As temperature increases, volume of the electrolyte decreases due to which there is rapid decrease of the mean free path which decreases the viscosity of the liquids, so the resistance of the electrolyte will also decrease as with an increase in temperature

Thus, the resistance of the electrolyte will decrease.

Objective I

Answer.1

|

When current passes through a resistor, the heat produced by Joule's heating effect is given by-

$$H = I^2Rt$$

where,

I =current

R = resistance of the resistor

t = time for which current is flowing

The graph shows the variation of the heat generated by the resistor with respect to the current.

Form the above equation, we get

$$I^2 = \frac{H}{R \times T}$$

Which is same as the equation of parabola.

Since, heat produced for a given time in a resistor varies with the square of current flowing through it.

Thus, the curve a is the correct option.

Answer.2

When current passes through a resistor, the heat produced by Joule's heating effect is given by-

$$H = I^2Rt$$

where,

I = current

R = resistance of the resistor

t = time for which current is flowing

Since with increase in the temperature of the resistor, its

resistance is also increased.

The rate of production of thermal energy $\frac{dU}{dt}$ in the resistor will be-

$$\frac{dU}{dt} = \frac{d}{dt}(i^2 Rt)$$

$= i^2 R$where

i = current flowing through the resistor and

R = resistance of the resistor

From above equation, the rate of production of thermal energy in

the resistor is directly proportional to the resistance.

Since, due to the heat generated by the resistance the operating temperature of the resistance increases given by the formula below:

$R=R_o(1+\alpha T)$

Where

Ro is the initial resistance of the resistor

α is the coefficient of thermal conductivity

T is the temperature

Thus, the resistance of the resistor start increasing with the increase in temperature.

From the graph,

$\frac{dU}{dt}$ also increases linearly with time starting from a point $\frac{dU}{dt} = i^2 R$, which is best shown by plot *d*.

Thus, option D is the correct option.

Answer.3

The value of neutral temperature is constant for a thermocouple.

It depends on the nature of materials and is independent of the

temperature of the cold junction.

Inversion temperature depends on the temperature of the cold

junction, as well as the nature of the material.

Thus, (b) is the correct option.

Answer.4

When current passes through a resistor, the heat produced by Joule's heating effect is given by-

$$H = I^2Rt$$

where,

I =current

R = resistance of the resistor

t = time for which current is flowing

Joule heat is directly proportional to the square of the current passing through the resistor.

We know,

Peltier heat is defined as the change in the temperature at the junction due to the flow of current in a circuit consists of two different kinds of conductor which lead to a heating or cooling effect is observed at the junction between the two material.

Peltier heat is directly proportional to the current passing through the junction.

Thomson heat is defined as the evolution or absorption of heat when electric current passes through a circuit composed of a single material that has a temperature difference along its length

Also, in case of Thomson heat is also directly proportional to the current passing through the section of the wire.

Answer.5

|

The Seebeck effect is a phenomenon, in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances.

The cause of this voltage difference is the diffusion or migration of free electrons from a higher electron-density region to a lower electron-density region.

The free electron-density of the electrons varies from metal to metal and also electron-density changes with change in temperature.

Hence, both the statements are the causes of Seebeck Effect.

Answer.6

|

Peltier effect is an effect whereby heat is given out or absorbed when an electric current passes across a junction between two materials.

These materials are generally metals.

Now, this is caused due to the difference in density of free electrons in different metals.

Thus, the option B is the correct option

Answer.7

|

Thomson effect is the process where the evolution or absorption of heat takes place when electric current passes through a circuit composed of a single material that has a temperature difference along its length.

If a metallic conductor has non-uniform temperature distribution along its length, the density of the free electrons varies for different sections.

The electrons diffuses from the region with higher concentration to the region with lower concentration of free electrons.

Thus, the free-electron density in a material depends on temperature for the Thomson effect.

Hence, option C is the correct option.

Answer.8

|

Faraday's constant is universal constant.

Its value is equal to 9.6845×10^{7} C/kg which is constant on entire universe.

It does not depend on the amount of the electrolyte, current in the electrolyte and on the amount of charge passed through the electrolyte.

Thus, option C is the correct option.

Objective II

Answer.1

|

When current passes through a resistor, the heat produced by Joule's heating effect is given by-

$$H = I^2Rt$$

where,

I =current

R = resistance of the resistor

t = time for which current is flowing

When the resistors are in series, the current through them will be same.

So, the amount of thermal energy evolved in the resistors is same for each of the resistor.

The rise or fall in the temperature of the resistance will depend on the shape and size of the resistor.

So, the rise in the temperature of the two resistances may become equal.

Answer.2

The copper strip AB and an iron strip AC are joined at A and the junction A is maintained at 0°C and the free ends B and C are maintained at 100°C as shown in fig.

Due to Seebeck effect, there will be generation of thermo-emf between the points that are at different temperatures.

Here, all junctions and ends are at different temperatures, i.e., the two ends of the copper, the copper end and the iron end at the junction, the two ends of the iron strip and the free ends B and C are at different temperatures.

Hence, a potential difference exists among them.

Answer.3

|

Thermocouples are of two wire legs made from different metals. These wires legs are welded together at one end, creating a junction.

This junction is where the temperature is measured.

When the change in temperature occurs at junction, a voltage is created.

Now neutral temperature for the thermocouple.is the temperature of the hot junction at which the thermo-emf in a thermocouple becomes maximum

For a thermocouple with constants *a* and *b* having the same sign, the neutral temperature will be less than the cold junction temperature of thermocouple, as

$$\theta_n = -\frac{a}{b}$$

Hence, there will be no neutral or inversion temperature, since the hot junction temperature cannot be less than the temperature of cold junction of thermocouple.

Answer.4

I

An electrolytic cell is an electrochemical cell that drives a non-spontaneous redox reaction through the application of electrical energy through the electrodes

Electrolytic cells have both the electrodes of the same material.

So, on reversing the terminals of the battery, the direction of the charge flow reverses, but the rate of the electrolysis will remain constant.

Answer.5

I

The electrochemical equivalent of a substance is defined as -

the mass of the chemical element (in grams) transported by 1 coulomb of electric charge.

The electrochemical equivalent of a substance is calculated by taking the ratio of the relative atomic mass of the substance to its valency.

Thus, it is only dependent on the nature of the material.

Exercises

Answer.1

Given-

Current through the wire, i = 2 AResistance of the wire, R = 25 ΩTime taken, t = 1 min = 60 sWe know Joule's heating effect, heat developed across the wire,

$$H = i^2 Rt$$

where,

I =current

R = resistance of the resistor

t = time for which current is flowing

Putting the value in the above formula, we get

$\Rightarrow H$ = 2 × 2 × 25 × 60= 100 × 60 J = 6000 J

Answer.2

Given-

Resistance of the coil, R = 100 Ω,Emf of the battery, V = 6 V,Change in temperature, ΔT = 15°C

Using Joule's heating effect heat produced across the coil,

$$H = \frac{V^2}{R} t$$

This heat generated is used to increase the temperature of the coil.

$\Rightarrow H = c\Delta T$

$\Rightarrow \frac{V^2}{R}t \ = c\Delta T$

$\Rightarrow \frac{6^2}{100}t \ = 4 \times 15$

$\Rightarrow t = \frac{6000}{36}$

$= 166.7\ s$

$= 2.8\ min$

Answer.3

Let the resistance of the coil be R

Given

voltage =250 V

power =500 W

The power P consumed by a coil of resistance R when connected across a supply V is given by Joule's heating effect -

$P \ = \frac{V^2}{R}t$

$\Rightarrow R \ = \frac{V^2}{p}$

$\Rightarrow R \ = \frac{250^2}{500}$

$= 125\ \Omega$

Now when, P = 1000 W

$\Rightarrow P \ = \frac{V^2}{R}t$

$= \frac{250^2}{1000}$

$= 62.5\ \Omega$

Answer.4

(a) Let *R* be the resistance of the coil.

Given, resistivity, $\rho = 1.0 \times 10^{-8}\ \Omega$ m

The power *P* consumed by a coil of resistance *R* when connected across a supply *V* is given by Joule's heating effect-

$$\Rightarrow P = \frac{V^2}{R}t$$

$$\Rightarrow R = \frac{V^2}{p}$$

$$\Rightarrow R = \frac{250^2}{500}$$

$= 125\ \Omega$

(b) We know resistance R is given by-

$$R = \frac{\rho \times l}{A}$$

where

ρ = resistivity of the material

l = length of the wire

A= area of cross section of the wire

Given, cross-sectional area of the wire is 0.5 mm^2

$$\Rightarrow l = \frac{RA}{\rho}$$

$$\Rightarrow l = \frac{125 \times 0.5 \times 10^{-6}}{10^{-6}}$$

$= 62.5\ m$

(c) Let *n* be the number of turns in the given coil.

Given, radius of each turn is 4.0 mm

Then,

$l = 2\pi r \times n$

Where,

l = length of the coil

r=radius of the coil

$\Rightarrow n = l2\pi r$

$\Rightarrow n = 62.52 \times 3.14 \times 4 \times 10^{-3}$

≈ 2500

Answer.5

Given

voltage = 250V

power p=100W

Resistivity of copper = $1.7 \times 10^{-8}\ \Omega$ m.

area of cross section 5 $mm^2 = 5 \times 10^{-6}$ m.

Let *R* be the resistance of the bulb.

If *P* is the power consumed by the bulb when operated at voltage *V*, then by Joule's heating effect-

$$\Rightarrow P = \frac{V^2}{R} t$$

$$\Rightarrow R = \frac{V^2}{p}$$

Putting the value in the above formula, we get

$$= \frac{250^2}{100}$$

$$= 625\ \Omega$$

Resistance of the copper wire is given by,

$$Rc = \frac{\rho l}{A}$$

where

l = length of the coil

ρ= resistivity of the coil

A= area of the coil

$$Rc\ = \frac{1.7\ \times\ 10^{-8}\ \times 10^5}{5\ \times 10^{-6}}$$

$$= 0.034\ \Omega$$

The effective resistance,

$$R_{eff} = R + R_c$$

$$= 625.034\ \Omega$$

The current supplied by the power station by ohm's law -

$$i = \frac{V}{R_{eff}}$$

$$= \frac{220}{625.034}\ A$$

The power supplied to one side of the connecting wire is given using Joule's heating effect,

$$P' = i^2 Rc$$

$$= \left(\frac{220}{625.034}\right)^2 \times 0.034$$

The total power supplied on both sides,

$$2P' = \left(\frac{220}{625.034}\right)^2 \times 0.034 \times 2$$

$$= 0.0084\ W$$

$$= 8.4\ mW$$

Answer.6

If P is the power consumed by the bulb when operated at voltage V, then by Joule's heating effect-

$$\Rightarrow P = \frac{V^2}{R}$$

$$\Rightarrow R = \frac{V^2}{p}$$

$$= \frac{220 \times 220}{60}$$

$$= 806.67\ \Omega$$

Now when the supply drops to $V' = 180$ V

The power consumed,

$$\Rightarrow P = \frac{V'^2}{R}$$

$$= \frac{180^2}{806.67}$$

$$= 40\ W$$

(b) Now the supply changes to, $V'' = 240$ V.

Therefore,

$$\Rightarrow P = \frac{V''^2}{R}$$

$$= \frac{240^2}{806.67}$$

$$= 71\ W$$

Answer.7

Given,

Output voltage, V = 220 V ± 1%

= 220 V ± 2.2 V

The resistance of a bulb that is operated at voltage V and consumes power P is given by Joule's heating effect-

$$\Rightarrow P = \frac{V'^2}{R}$$

Putting the values in the above formula, we get

$$= \frac{(220)^2}{100}$$

$$\Rightarrow R = \frac{48400}{100}$$

$= 484\ \Omega$

(a) We know that for minimum power to be consumed, output voltage should be minimum.

The minimum output voltage will be, $V' = (220 - 2.2)\ V = 217.8\ V$

The current through the bulb, $i' = \frac{V'}{R}$

Where

V is the voltage across the bulb

R is the resistance of the bulb

Putting the values in the above formula, we get

$$= \frac{217.8}{484}$$

=0.45 A

Now, the power consumed by the bulb,

$P' = i' \times V' = 0.45 \times 217.8$

$= 98.0\ W$

(b) For maximum power to be consumed, output voltage should be maximum.

The maximum output voltage,

$V'' = (220 + 2.2)\ V = 222.2\ V$

The current through the bulb,

$i'' = V''R$

$= 222.2484$

$= 0.459\ A$

Power consumed by the bulb in this case is,

$P'' = i'' \times V'' = 0.459 \times 222.2$

$= 102\ W$

Answer.8

Given

The operating voltage is *V* and power consumed is *P*.

Therefore, the resistance of the bulb can be calculated as follows,

$\Rightarrow P = \frac{V^2}{R}$

$\Rightarrow R = \frac{V^2}{p}$

Putting the values in the above formula, we get

$= (220 \times 220)100$

$= 484\ \Omega$

The power fluctuations is given as *p* = 150 W

So, the voltage fluctuation that the bulb can withstand is given by-

Resistance of the bulb, $R = \frac{V^2}{p}$

Where

V is the velocity

P is the power fluctuations

$\Rightarrow V = \sqrt{R \times p}$

$= \sqrt{150 \times 484}$

$= 269.4\ V$

$= 270\ V$

Hence the bulb will withstand fluctuations up to 270 V.

Answer.9

Given

The operating voltage V

Power consumed P,

Now the resistance of the immersion heater,

$$R = \frac{V^2}{p}$$

$$= \frac{220^2}{1000}$$

$= 48.4\ \Omega$

Mass of water m is ,

m =1100× 1000

= 10 Kg

We know specific heat of water, s = 4200 $Jkg^{-1}\ K^{-1}$

Given rise in temperature, θ = 25°C

Heat required to raise the temperature of the given mass of water is given by –

$Q = m \times s \times \theta$

$= 10 \times 4200 \times 25$

$= 1050000\ J$

Let t be the time taken to raise the temperature of water.

Given the heat evolve is only 60%.

So,

$V^2R \times t \times 60\% = 1050000\,J$

$\Rightarrow (220)248.4 \times t \times 60100 = 1050000$

$\Rightarrow t = 29.17\ minutes$

Answer.10

Given-

Time taken to boil 4 cups of water, t = 2 minutesVolume of water boiled = 4 × 200 cc = 800 ccInitial temperature, θ_1 = 25°CFinal temperature, θ_2 = 100°CChange in temperature, $\theta = \theta_2 - \theta_1$ = 75°CMass of water required to boil , m = 800 × 1 = 800 gm = 0.8 Kg

Now heat required for boiling water,$Q = m \times s \times \theta$

Where

m is the mass of the water

s is the specific heat of the water

θ is the change in temperature

Putting the value in the above formula, we get

$= 0.8 \times 4200 \times 75$

$= 252000\,J$

We know, to convert watt-hour to watt-sec,

1000 watt – hour = 1000 × 3600 watt sec.

Hence cost of boiling 4 cups of water

$= 11000 \times 3600 \times 252000$

$= Rs. 0.7$

(b)

Given,

Initial temperature, θ_1 = 5°CFinal temperature, θ_2 = 100°CChange in temperature, θ = $\theta_2 - \theta_1$ = 95°C

heat required for boiling water,$Q = m \times s \times \theta$

Where

m is the mass of the water

s is the specific heat of the water

θ is the change in temperature

Putting the value in the above formula, we get

= 0.8 × 4200 × 95

= 319200

Again converting into watt-second,Cost of boiling 4 cups of water

=11000×3600×319200

= Rs 0.09

Answer.11

Case-I

Given -

When the supply voltage is 220 V.Power consumed by the bulb = 100 WExcess power = 100 − 40 = 60 W

Hence, power converted to light = 60% of 60 W

= 36 W

Case-II

Given

When the supply voltage is 200 V.

Power consumed, $P = \frac{V^2}{R}$

Where

P is the power consumed by the bulb

V is the voltage

Putting the values in the above formula, we get

$$\frac{200^2}{\frac{220^2}{100}} = 82.64\,W\ (2)$$

Excess power

= 82.64 – 40 = 42.64 W

Power converted to light = 60% of 42.64 W = 25.584 W

Percentage drop in the light intensity is-

$$p = 36 - (25.58436 \times 100)$$

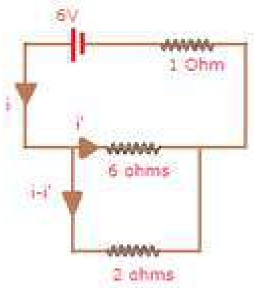
$$\Rightarrow p = 28.93 \approx 29\%$$

Answer.12

Given-

Resistance - 2.0 ΩΩ

heat capacity of the calorimeter together with water = 2000 J K^{-1}



Looking into the circuit the effective resistance of the circuit,

2.0 Ω in parallel with 6.0 Ω and this combination in series with 1.0 Ω

$$R_{eff} = \frac{6 \times 2}{6 + 2} + 1$$

$$= \frac{5}{2}\ \Omega$$

Now, current *i* through the circuit, from ohm's law-

$$i = \frac{V}{Reff}$$

$$= \frac{6}{5/2}$$

$$= \frac{12}{5}\ A$$

Let take *i'* as the current through the 6 Ω resistor.

Then, applying KCL, the algebraic sum of current entering and leaving a node is zero and from ohm's law, we can write -

$$i' \times 6 = (i - i') \times 2$$

$$\Rightarrow 6i' = 125 \times 2 - 2i'$$

$$\Rightarrow 8i' = 245$$

$$\Rightarrow i' = \frac{245}{8}$$

$$= 35\ A$$

$$\Rightarrow\ i - i' = 125 - 35 = 95\ A\ (1)$$

(a) Heat generated in the 2 Ω resistor, using Joule's Heating effect

$$H = (i - i')^2 R \times t$$

from (1) and substituting values

$\Rightarrow H = 95 \times 95 \times 2 \times 15 \times 60$

$= 5832\, J$

Given that the heat capacity of the calorimeter together with water is 2000 J K^{-1}

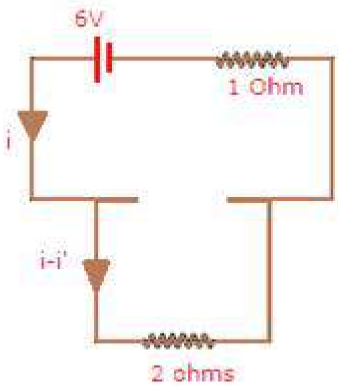
Which means , 2000 J of heat raise the temp by 1 K.

Then, 5832 J of heat raises the temperature of water by

$$\frac{5832}{2000} = 2.916\, K$$

(b) When the 6 Ω resistor burn out, the effective resistance of the

circuit will become –



$R_{eff} = 1 + 2 = 3\, \Omega$

Current through the circuit,

$$i = \frac{V}{R_{eff}} = \frac{6}{3} = 2\, A$$

Heat generated in the 2 Ω resistor, using Joule's Heating effect

$(2)^2 \times 2 \times 15 \times 60$

$= 7200\, J$

Given that the heat capacity of the calorimeter together with water is 2000 J K^{-1}

Which means , 2000 J of heat raise the temp by 1 K.

So, 7200J will raise the temperature by

$$\frac{7200}{2000} = 3.6\, K\, .$$

Answer.13

GivenDifference in temperature of junctions, θ = 0.001°C,a = – 46 × 10^{-6} V °$C^{-1}$$b$ = – 0.48 × 10^{-5} V °C^{-2}.

We, know emf E is given by-

$$E = a\theta + 12b\theta^2$$

Putting the value in the above equation, we get

$$\Rightarrow E = (-46 \times 10^{-6}) \times (0.001) - 12 \times (0.48 \times 10^{-6}) \times (0.001)^2$$

$$= -46 \times 10^{-9} - 0.24 \times 10^{-12} = -46.0024 \times 10^{-9} = -4.6 \times 10^{-8} V$$

Answer.14

Given –

Difference in temperature, θ = 40°C

Emf, E developed across junction is given by -

$$E = a\theta + 12b\theta^2 \ (1)$$

From table –

$$a_{cs} = [2.76 - (-43.7)] \mu V$$

$$= 46.46 \mu V/°C$$

$$b_{cs} = [0.012 - (-0.47)] \mu V/°C$$

$$= 0.482 \mu V/°C^2$$

Substituting in eq. (1),

$$Ecs = 46.46 \times 10^{-6} \times 40 + 12 \times 0.482 \times 10^{-6} \times (40)2$$

$$= 1.04 \times 10^{-5} V$$

Answer.15

Neutral temperature is given by -

$$\theta n = -\frac{a}{b}$$

Using table data –

a_{CuFe}

$= a_{CuPb} - a_{FePb}$

$= 2.76 - 16.6$

$= 13.84\ \mu V°C^{-1}$

Similarly

b_{CuFe}

$= b_{CuPb} - b_{FePb}$

$= 0.012 + 0.030$

$= 0.042\ \mu V°C^{-2}$

Thus, the neutral temperature becomes,

$$\theta n = -\frac{a_{CuFe}}{b_{CuFe}}$$

$$= \frac{13.84}{0.042}$$

$= 329.52\ °C$

$= 330\ °C$

Since, temperatures is in Celsius, the inversion temperature is double the neutral temperature, i.e. 659°C.

Answer.16

(a) monovalent material –

We know

1 F (farady) is 1 mol of electrons

⇒1 F = one electron (1.602 x 10^{-19}) ×Avogadro's number (6.022 x 10^{23})

=96,500 C of charge

We know that amount of charge required by 1 equivalent mass of the substance = 96500 C

For a monovalent material, equivalent mass is its molecular mass

⇒ Amount of charge required by 6.023 × 10^{23} atoms which is the Avogadro's Number and is equal to 96500 C of charge

Therefore ,amount of charge required by 1 atom =

$$\frac{96500}{6.023 \times 10^{23}} = 1.6 \times 10^{-19}\,C$$

(b) For a divalent material-

As we know equivalent mass(1U) is 12 times its molecular mass(Z)

We know

1 F (faraday) is 1 mol of electrons

⇒1 F = one electron (1.602 x 10^{-19}) ×Avogadro's number (6.022 x 10^{23})

= 96,500 C of charge

⇒ Amount of charge required is 12 times of 6.023 × 10^{23} =

= 96500 C of charge

⇒ Amount of charge required by 1 atom for a divalent material is –

$$= 1.6 \times 2 \times 10^{-19} = 3.2 \times 10^{-19}\,C$$

Answer.17

Given

Equivalent mass of silver E_{Ag} = 107.9 g

Current passed = 0.005 A

We know

1 F (faraday) is 1 mol of electrons

⇒1 F = one electron (1.602×10^{-19}) ×Avogadro's number (6.022×10^{23})

= 96,500 C of charge

⇒ Amount of charge required is 12 times of 6.023 × 10 =

= 96500 C of charge

The Electrochemical equivalent of silver,

$$Z_{Ag} = \frac{E}{A_{gf}}$$

Where

E is the equivalent mass of silver

A_{gf} is the amount of charge

$$= \frac{107.9}{96500}$$

$$= 0.001118$$

Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

we get:

$$m = 0.00118 \times 0.500 \times 3600$$

$$= 2.01\, g$$

So, 2.01 g of silver is liberated on electrode.

Answer.18

Given-Mass of silver deposited, $m = 3$ g

Time taken, $t = 3$ min. = 180 s

Electrochemical equivalent of silver, $Z = 1.12 \times 10^{-6}$ kg C^{-1}

Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

substituting the values

$$3 \times 10^{-3} = 1.12 \times 10^{-6} \times i \times 180$$

$$\Rightarrow i = \frac{3 \times 10^{-3}}{1.12 \times 10^{-6} \times 180}$$

$$\Rightarrow i = 14.89 \approx 15\ A$$

Answer.19

GivenMass of 1 liter hydrogen,

m=222.4 g

Current = 5A

Let t be required time

Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

substituting the values,

$$\frac{2}{22.4} = \frac{5 \times t}{96500}$$

$$\Rightarrow t = 1723.21\ s$$

$$= 28.7\ minutes \approx 29\ minutes$$

Answer.20

Given-Mass of salt deposited, m = 1

gCurrent, i = 2 A

Time, t = 1.5 hours = 5400 s

Atomic weight of silver is 107.9 g mol^{-1}.

For the trivalent metal salt

Equivalent mass = 13 times its Atomic weight

The E.C.E of the salt

Z=Equivalent mass

96500=Atomic weight 3×96500

(a) Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

Now, 1 gram is deposited and the element is trivalent metal

$$1 \times 10^{-3} = \frac{Atomic\ weight\ \times 2 \times 5400}{3 \times 96500}$$

$$\Rightarrow Atomic\ weight = \frac{3 \times 96500 \times 10^{-3}}{2\ \times 5400}$$

$$= 26.8 \times 10 - 3\ kg/mole$$

$$\Rightarrow Atomic\ weight = 26.8\ g/mole$$

(b)Now the relation between equivalent mass and mass deposited on plates is given by –

$$E_1 E_2 = m_1 m_2$$

Where

E1 is the equivalent mass of the trivalent metal

E2 is the equivalent mass of the silver

m_1 is the mass of trivalent material deposited

m_2 is the mass of the silver deposited

Atomic weight of silver is 107.9 g mol^{-1}.

Substituting to calculate the mass deposited –

$$\Rightarrow 26.83 \times 107.9 = 1\ \times m_2$$

$$\Rightarrow m_2 = 12.1\ g$$

Answer.21

Given-Current passing, *i* = 15 ASurface area of the plate = 200 cm^2,Thickness of silver deposited= 0.1 mm = 0.01 cm

Volume of Ag deposited on one side = 200 × 0.01 cm^3 = 2 cm^3

Volume of Ag deposited on both side = 2 ×2 cm^3 = 4 cm^3

The specific gravity of silver = 10.5

Atomic weight = 107.9 g mol^{-1}

Now, mass of silver deposited, m can be calculated

m = Volume × Specific gravity × 1000

putting the value in the above formula, we get

$= 4 \times 10^{-3} \times 10.5 \times 1000$

= 42 kg

Using the formula, from faraday's law of electrolysis –

$m = Zit$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

Substituting the values

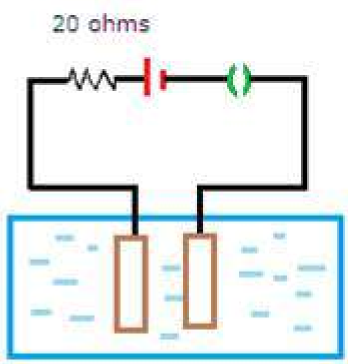
$42 = Z_{Ag} \times 15 \times t$

$\Rightarrow t = \frac{42 \times 96500}{107.9 \times 15}$

$\Rightarrow t = 2504.17\ s$

$= 42\ minutes$

Answer.22



Given:Mass of silver deposited, m = 2.68 g

Time, t = 10 minutes = 600 s

Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

$$2.68 \times 10^{-3} = 107.9 \times 10^{-3} 96500 \times i \times 600$$

$$\Rightarrow i = \frac{2.68 \times 96500}{107.9 \times 600}$$

$$\Rightarrow i = 3.99$$

$$= 4\ A$$

Now, heat developed in the 20 Ω resistor from Joule's heating effect,

$$H = i^2 RT$$

Where

I is the current in the circuit

R is the resistance of the resistor

T is the time period for which the current is allowed to flow through the circuit

Putting the above values in the formula, we get

$$\Rightarrow H = 4^2 \times 20 \times 600$$

$$\Rightarrow H = 192000\ J$$

$$= 192\ kJ$$

Answer.23

Let the current through the circuit *i* be.

Emf of battery, $E = 12$ V

Voltage drop across the voltmeter, $V = 10$ V

Internal resistance of the battery, $r = 2\ \Omega$

Applying Kirchhoff's Law, the algebraic sum of voltage and voltage drop in the circuit is zero,

we get

$$E = V + ir$$

Where, E = battery emf

V=voltage drop

r=internal resistance

I = current through the circuit

$$\Rightarrow i = \frac{E - V}{r}$$

$$= \frac{12 - 10}{2}$$

$$= 1\ A$$

Using the formula, from faraday's law of electrolysis –

$$m = Zit$$

where,

m = the mass of the substance deposited on the electrode

z=electrochemical equivalence

i=current passing

t=time taken

$$m = \frac{107.9 \times 1 \times 0.5 \times 3600}{96500}$$

$= 2.01\ g$

Answer.24

Given

Surface area of the plate, A = 10 cm^2 = 10 × 10^{-4} m^2

Thickness of copper deposited, t = 10 μm = 10^{-5} m

Density of copper = 9000 kg/m^3

Electrochemical equivalent of copper −3 × 10^{-7} kg C^{-1}

specific heat capacity of water – 4200 J kg^{-1} K^{-1}

Volume, V of copper deposited,

$V = A \times (2t)$

Where

A is the area of the plates

t is the thickness of the plates

Putting the values in the above formula, we get

$\Rightarrow V = 10 \times 10^{-4} \times 2 \times 10 \times 10^{-6}$

$= 2 \times 10^{2} \times 10^{-10}$

$= 2 \times 10^{-8}\ m^3$

We know, mass of copper deposited,

m = Volume × Density

$= 2 \times 10^{-8} \times 9000$

$\Rightarrow m = 18 \times 10^{-5}\ kg$

Using the Faraday's Laws

$m = ZQ$

where

m = mass of the substance

Q= charge

Z= Electrochemical equivalent

Putting the values in the above formula, we get$\Rightarrow 18 \times 10^{-5} = 3 \times 10^{-7} \times Q$

$\Rightarrow Q = 6 \times 10^{2}$ C

Now,

The energy spent by the cell will be = Work done by the cell

$\Rightarrow W = V \times Q$

Where

V is the potential difference

Q is the charge

Putting the values in the above formula, we get

$= 12 \times 6 \times 10^{2}$

$= 72 \times 10^{2}$ = 7.2 kJ

Let us take $\Delta\theta$ as the rise in temperature of water.

If this amount of energy is used to heat 100 g of water, then-

Q = c×m ×$\Delta\theta$

Where,

c= specific heat of water

Q= Heat

m = mass of water

$\Delta\theta$ = change in temperature

Substituting

$\Rightarrow 7.2 \times 10^{3} = 100 \times 10^{-3} \times 4200 \times \Delta\theta$

$\Rightarrow \Delta\theta = 17$ K