$= (12\text{ V})(0{\cdot}4\text{ A})(30 \times 60\text{ s}) = 8{\cdot}64\text{ kJ}.$

8. *A current of 1 A is passed through a dilute solution of sulphuric acid for some time to liberate 1 g of oxygen. How much hydrogen is liberated during this period? How long was the current passed? Faraday constant = 96500 C/mole.*

Solution : The relative atomic mass of oxygen = 16 and its valency = 2 so that the chemical equivalent $E = \frac{16}{2} = 8.$ Chemical equivalent of hydrogen = 1.

$$\frac{m_{oxygen}}{m_{hydrogen}} = \frac{E_{oxygen}}{E_{hydrogen}} = \frac{8}{1}$$

or, $$m_{hydrogen} = \frac{m_{oxygen}}{8} = \frac{1\text{ g}}{8} = 0{\cdot}125\text{ g}.$$

We have, 1 g of oxygen $= \frac{1}{8}$ gram-equivalent.

The charge needed to liberate $\frac{1}{8}$ gram-equivalent

$$= \frac{1}{8}\text{ faraday}$$

$$= \frac{96500}{8}\text{ C} = 1{\cdot}12 \times 10^4\text{ C}.$$

As the current is 1 A, the time taken is

$$t = \frac{Q}{i} = \frac{1{\cdot}2 \times 10^4\text{ C}}{1\text{ A}}$$

$$= 1{\cdot}2 \times 10^4\text{ s}$$

$$= 3\text{ hours }20\text{ minutes.}$$

□

QUESTIONS FOR SHORT ANSWER

1. If a constant potential difference is applied across a bulb, the current slightly decreases as time passes and then becomes constant. Explain.
2. Two unequal resistances R_1 and R_2 are connected across two identical batteries of emf $\mathcal{E}$ and internal resistance r (figure 33-Q1). Can the thermal energies developed in R_1 and R_2 be equal in a given time. If yes, what will be the condition?

Figure 33-Q1

3. When a current passes through a resistor, its temperature increases. Is it an adiabatic process?
4. Apply the first law of thermodynamics to a resistor carrying a current i. Identify which of the quantities ΔQ, ΔU and ΔW are zero, wich are positive and which are negative.
5. Do all the thermocouples have a neutral temperature?
6. Is inversion temperature always double of the neutral temperature? Does the unit of temperature have an effect in deciding this question?
7. Is neutral temperature always the arithmetic mean of the inversion temperature and the temperature of the cold junction? Does the unit of temperature have an effect in deciding this question?
8. Do the electrodes in an electrolytic cell have fixed polarity like a battery?
9. As temperature increases, the viscosity of liquids decreases considerably. Will this decrease the resistance of an electrolyte as the temperature increases?

OBJECTIVE I

1. Which of the following plots may represent the thermal energy produced in a resistor in a given time as a function of the electric current?

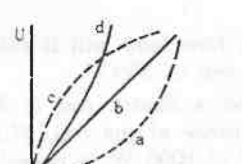


Figure 33-Q2

2. A constant current i is passed through a resistor. Taking the temperature coefficient of resistance into account, indicate which of the plots shown in figure (33-Q3) best

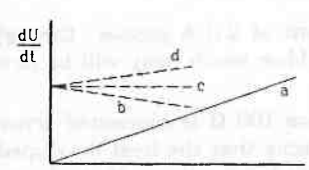


Figure 33-Q3

represents the rate of production of thermal energy in the resistor.

3. Consider the following statements regarding a thermocouple.
(A) The neutral temperature does not depend on the temperature of the cold junction.
(B) The inversion temperature does not depend on the temperature of the cold junction.
(a) Both A and B are correct.
(b) *A* is correct but B is wrong.
(c) *B* is correct but A is wrong.
(d) Both A and B are wrong.

4. The heat developed in a system is proportional to the current through it.
(a) It cannot be Thomson heat.
(b) It cannot be Peltier heat.
(c) It cannot be Joule heat.
(d) It can be any of the three heats mentioned above.

5. Consider the following two statements.
(A) Free-electron density is different in different metals.
(B) Free electron density in a metal depends on temperature.
Seebeck effect is caused
(a) due to both A and B
(b) due to A but not due to B
(c) due to B but not due to A
(d) neither due to A nor due to B.

6. Consider the statements A and B in the previous question. Peltier effect is caused
(a) due to both A and B
(b) due to A but not due to B
(c) due to B but not due to A
(d) neither due to A nor due to B.

7. Consider the statements A and B in question 5. Thomson effect is caused
(a) due to both A and B
(b) due to A but not due to B
(c) due to B but not due to A
(d) neither due to A nor due to B.

8. Faraday constant
(a) depends on the amount of the electrolyte
(b) depends on the current in the electrolyte
(c) is a universal constant
(d) depends on the amount of charge passed through the electrolyte.

OBJECTIVE II

1. Two resistors having equal resistances are joined in series and a current is passed through the combination. Neglect any variation in resistance as the temperature changes. In a given time interval,
(a) equal amounts of thermal energy must be produced in the resistors
(b) unequal amounts of thermal energy may be produced
(c) the temperature must rise equally in the resistors
(d) the temperature may rise equally in the resistors.

2. A copper strip *AB* and an iron strip *AC* are joined at *A*. The junction *A* is maintained at 0°C and the free ends *B* and *C* are maintained at 100°C. There is a potential difference between
(a) the two ends of the copper strip
(b) the copper end and the iron end at the junction
(c) the two ends of the iron strip
(d) the free ends *B* and *C*.

3. The constants a and b for the pair silver–lead are $2{\cdot}50\ \mu V/°C$ and $0{\cdot}012\ \mu V/(°C)^2$ respectively. For a silver–lead thermocouple with colder junction at 0°C,
(a) there will be no neutral temperature
(b) there will be no inversion temperature
(c) there will not be any thermo-emf even if the junctions are kept at different temperatures
(d) there will be no current in the thermocouple even if the junctions are kept at different temperatures.

4. An electrolysis experiment is stopped and the battery terminals are reversed.
(a) The electrolysis will stop.
(b) The rate of liberation of material at the electrodes will increase.
(c) The rate of liberation of material will remain the same.
(d) Heat will be produced at a greater rate.

5. The electrochemical equivalent of a material depends on
(a) the nature of the material
(b) the current through the electrolyte containing the material
(c) the amount of charge passed through the electrolyte
(d) the amount of this material present in the electrolyte.

EXERCISES

1. An electric current of 2·0 A passes through a wire of resistance 25 Ω. How much heat will be developed in 1 minute ?

2. A coil of resistance 100 Ω is connected across a battery of emf 6·0 V. Assume that the heat developed in the coil is used to raise its temperature. If the heat capacity of the coil is 4·0 J/K, how long will it take to raise the temperature of the coil by 15°C ?

3. The specification on a heater coil is 250 V, 500 W. Calculate the resistance of the coil. What will be the resistance of a coil of 1000 W to operate at the same voltage ?

4. A heater coil is to be constructed with a nichrome wire ($\rho = 1{\cdot}0 \times 10^{-6}\ \Omega$–m) which can operate at 500 W when connected to a 250 V supply. (a) What would be the resistance of the coil? (b) If the cross-sectional area of the wire is $0{\cdot}5\ mm^2$, what length of the wire will be needed? (c) If the radius of each turn is 4·0 mm, how many turns will be there in the coil?

5. A bulb with rating 250 V, 100 W is connected to a power supply of 220 V situated 10 m away using a copper wire of area of cross-section $5\ mm^2$. How much power will be consumed by the connecting wires? Resistivity of copper $= 1{\cdot}7 \times 10^{-8}\ \Omega$–m.

6. An electric bulb, when connected across a power supply of 220 V, consumes a power of 60 W. If the supply drops to 180 V, what will be the power consumed? If the supply is suddenly increased to 240 V, what will be the power consumed?

7. A servo voltage stabiliser restricts the voltage output to 220 V ± 1%. If an electric bulb rated at 220 V, 100 W is connected to it, what will be the minimum and maximum power consumed by it?

8. An electric bulb marked 220 V, 100 W will get fused if it is made to consume 150 W or more. What voltage fluctuation will the bulb withstand?

9. An immersion heater rated 1000 W, 220 V is used to heat $0{\cdot}01\ m^3$ of water. Assuming that the power is supplied at 220 V and 60% of the power supplied is used to heat the water, how long will it take to increase the temperature of the water from 15°C to 40°C?

10. An electric kettle used to prepare tea, takes 2 minutes to boil 4 cups of water (1 cup contains 200 cc of water) if the room temperature is 25°C. (a) If the cost of power consumption is Rs. 1·00 per unit (1 unit = 1000 watt–hour), calculate the cost of boiling 4 cups of water. (b) What will be the corresponding cost if the room temperature drops to 5°C?

11. The coil of an electric bulb takes 40 watts to start glowing. If more than 40 W is supplied, 60% of the extra power is converted into light and the remaining into heat. The bulb consumes 100 W at 220 V. Find the percentage drop in the light intensity at a point if the supply voltage changes from 220 V to 200 V.

12. The 2·0 Ω resistor shown in figure (33-E1) is dipped into a calorimeter containing water. The heat capacity of the calorimeter together with water is 2000 J/K. (a) If the circuit is active for 15 minutes, what would be the rise in the temperature of the water? (b) Suppose the 6·0 Ω resistor gets burnt. What would be the rise in the temperature of the water in the next 15 minutes?

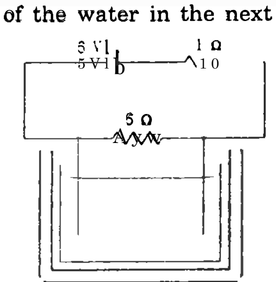


Figure 33-E1

13. The temperatures of the junctions of a bismuth–silver thermocouple are maintained at 0°C and 0·001°C. Find the thermo-emf (Seebeck emf) developed. For bismuth–silver, $a = -46 \times 10^{-6}$ V/deg and $b = -0{\cdot}48 \times 10$ V/deg^2.

14. Find the thermo-emf developed in a copper–silver thermocouple when the junctions are kept at 0°C and 40°C. Use the data in table (33.1).

15. Find the neutral temperature and inversion temperature of copper–iron thermocouple if the reference junction is kept at 0°C. Use the data in table (33.1).

16. Find the charge required to flow through an electrolyte to liberate one atom of (a) a monovalent material and (b) a divalent material.

17. Find the amount of silver liberated at cathode if 0·500 A of current is passed through $AgNO_3$ electrolyte for 1 hour. Atomic weight of silver is 107·9 g/mole.

18. An electroplating unit plates 3·0 g of silver on a brass plate in 3·0 minutes. Find the current used by the unit. The electrochemical equivalent of silver is $1{\cdot}12 \times 10^{-6}$ kg/C.

19. Find the time required to liberate 1·0 litre of hydrogen at STP in an electrolytic cell by a current of 5·0 A.

20. Two voltameters, one having a solution of silver salt and the other of a trivalent-metal salt, are connected in series and a current of 2 A is maintained for 1·50 hours. It is found that 1·00 g of the trivalent-metal is deposited. (a) What is the atomic weight of the trivalent metal? (b) How much silver is deposited during this period? Atomic weight of silver is 107·9 g/mole.

21. A brass plate having surface area $200\ cm^2$ on one side is electroplated with 0·10 mm thick silver layers on both sides using a 15 A current. Find the time taken to do the job. The specific gravity of silver is 10·5 and its atomic weight is 107·9 g/mol.

22. Figure (33-E2) shows an electrolyte of AgCl through which a current is passed. It is observed that 2·68 g of silver is deposited in 10 minutes on the cathode. Find the heat developed in the 20 Ω resistor during this period. Atomic weight of silver is 107·9 g/mole.

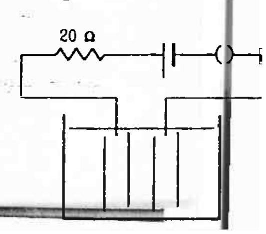


Figure 33-E2

23. The potential difference across the terminals of a battery of emf 12 V and internal resistance 2 Ω drops to 10 V when it is connected to a silver voltameter. Find the silver deposited at the cathode in half an hour. Atomic weight of silver is 107·9 g/mole.

24. A plate of area 10 cm* is to be electroplated with copper (density 9000 kg/m^3) to a thickness of 10 micrometres on both sides, using a cell of 12 V. Calculate the energy spent by the cell in the process of deposition. If this

energy is used to heat 100 g of water, calculate the rise in the temperature of the water. ECE of copper $= 3 \times 10^{-7}$ kg/C and specific heat capacity of water $= 4200$ J/kg-K.

□

ANSWERS

OBJECTIVE I

1. (a)	2. (d)	3. (b)	4. (c)	5. (a)	6. (b)
7. (c)	8. (d)				

OBJECTIVE II

1. (a), (d)	2. all	3. (a), (b)
4. (c)	5. (a)	

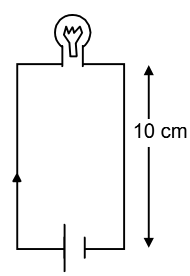
EXERCISES

1. 6.0×10^{3} J
2. 2·8 min
3. 125 Ω, 62·5 Ω
4. (a) 125 Ω (b) 62·5 m (c) ≈ 2500 turns
5. 8·4 mW
6. 40 W, 71 W
7. 98 V, 102 W
8. up to 270 V
9. 29 minutes
10. (a) 7 paisa (b) 9 paisa
11. 29%
12. (a) 2·9°C (b) 3·6°C
13. -4.6×10^{-8} V
14. 1.04×10^{-5} V
15. 330°C, 659°C
16. (a) 1.6×10^{-19} C (b) 3.2×10^{-19} C
17. 2·01 g
18. 15 A
19. 29 minutes
20. (a) 26·8 g/mole (b) 12·1 g
21. 42 minutes
22. 190 kJ
23. 2 g
24. 7·2 kJ, 17 K

□

CHAPTER – 33
THERMAL AND CHEMICAL EFFECTS OF ELECTRIC CURRENT

1. $i = 2$ A, $r = 25\ \Omega$,
   $t = 1$ min $= 60$ sec
   Heat developed $= i^2 RT = 2 \times 2 \times 25 \times 60 = 6000$ J
2. $R = 100\ \Omega$, $E = 6$ v
   Heat capacity of the coil = 4 J/k $\Delta T = 15°c$
   Heat liberate $\Rightarrow \frac{E^2}{Rt} = 4$ J/K × 15
   $\Rightarrow \frac{6 \times 6}{100} \times t = 60 \Rightarrow t = 166.67$ sec $= 2.8$ min
3. (a) The power consumed by a coil of resistance R when connected across a supply v is $P = \frac{v^2}{R}$
   The resistance of the heater coil is, therefore $R = \frac{v^2}{P} = \frac{(250)^2}{500} = 125\ \Omega$
   (b) If P = 1000 w then $R = \frac{v^2}{P} = \frac{(250)^2}{1000} = 62.5\ \Omega$
4. $f = 1 \times 10^{-6}\ \Omega$m $P = 500$ W $E = 250$ v
   (a) $R = \frac{V^2}{P} = \frac{250 \times 250}{500} = 125\ \Omega$
   (b) $A = 0.5$ mm$^2 = 0.5 \times 10^{-6}$ m$^2 = 5 \times 10^{-7}$ m^2
   $R = \frac{fl}{A} = l = \frac{RA}{f} = \frac{125 \times 5 \times 10^{-7}}{1 \times 10^{-6}} = 625 \times 10^{-1} = 62.5$ m
   (c) $62.5 = 2\pi r \times n$, $62.5 = 3 \times 3.14 \times 4 \times 10^{-3} \times n$
   $\Rightarrow n = \frac{62.5}{2 \times 3.14 \times 4 \times 10^3} \Rightarrow n = \frac{62.5 \times 10^{-3}}{8 \times 3.14} \approx 2500$ turns
5. $V = 250$ V $P = 100$ w
   $R = \frac{v^2}{P} = \frac{(250)^2}{100} = 625\ \Omega$



   Resistance of wire $R = \frac{fl}{A} = 1.7 \times 10^{-8} \times \frac{10}{5 \times 10^{-6}} = 0.034\ \Omega$
   $\therefore$ The effect in resistance $= 625.034\ \Omega$
   $\therefore$ The current in the conductor $= \frac{V}{R} = \left(\frac{220}{625.034}\right)$ A
   $\therefore$ The power supplied by one side of connecting wire $= \left(\frac{220}{625.034}\right)^2 \times 0.034$
   $\therefore$ The total power supplied $= \left(\frac{220}{625.034}\right)^2 \times 0.034 \times 2 = 0.0084$ w $= 8.4$ mw
6. $E = 220$ v $P = 60$ w
   $R = \frac{V^2}{P} = \frac{220 \times 220}{60} = \frac{220 \times 11}{3}\ \Omega$
   (a) $E = 180$ v $P = \frac{V^2}{R} = \frac{180 \times 180 \times 3}{220 \times 11} = 40.16 \approx 40$ w

(b) E = 240 v $\qquad P = \dfrac{V^2}{R} = \dfrac{240 \times 240 \times 3}{220 \times 11} = 71.4 \approx 71$ w

7. Output voltage = 220 ± 1% $\qquad$ 1% of 220 V = 2.2 v

The resistance of bulb $R = \dfrac{V^2}{P} = \dfrac{(220)^2}{100} = 484\ \Omega$

(a) For minimum power consumed $V_1 = 220 - 1\% = 220 - 2.2 = 217.8$

$\therefore\ i = \dfrac{V_1}{R} = \dfrac{217.8}{484} = 0.45$ A

Power consumed = $i \times V_1 = 0.45 \times 217.8 = 98.01$ W

(b) for maximum power consumed $V_2 = 220 + 1\% = 220 + 2.2 = 222.2$

$\therefore\ i = \dfrac{V_2}{R} = \dfrac{222.2}{484} = 0.459$

Power consumed = $i \times V_2 = 0.459 \times 222.2 = 102$ W

8. V = 220 v $\qquad$ P = 100 w

$R = \dfrac{V^2}{P} = \dfrac{220 \times 220}{100} = 484\ \Omega$

P = 150 w $\qquad V = \sqrt{PR} = \sqrt{150 \times 22 \times 22} = 22\sqrt{150} = 269.4 \approx 270$ v

9. P = 1000 $\qquad$ V = 220 v $\qquad R = \dfrac{V^2}{P} = \dfrac{48400}{1000} = 48.4\ \Omega$

Mass of water = $\dfrac{1}{100} \times 1000 = 10$ kg

Heat required to raise the temp. of given amount of water = $ms\Delta t = 10 \times 4200 \times 25 = 1050000$

Now heat liberated is only 60%. So $\dfrac{V^2}{R} \times T \times 60\% = 1050000$

$\Rightarrow \dfrac{(220)^2}{48.4} \times \dfrac{60}{100} \times T = 1050000 \Rightarrow T = \dfrac{10500}{6} \times \dfrac{1}{60}$ nub = 29.16 min.

10. Volume of water boiled = 4 × 200 cc = 800 cc

$T_1 = 25°C \qquad T_2 = 100°C \qquad \Rightarrow T_2 - T_1 = 75°C$

Mass of water boiled = 800 × 1 = 800 gm = 0.8 kg

Q(heat req.) = $MS\Delta\theta = 0.8 \times 4200 \times 75 = 252000$ J.

1000 watt – hour = 1000 × 3600 watt-sec = 1000× 3600 J

No. of units = $\dfrac{252000}{1000 \times 3600} = 0.07$ = 7 paise

(b) Q = $mS\Delta T = 0.8 \times 4200 \times 95$ J

No. of units = $\dfrac{0.8 \times 4200 \times 95}{1000 \times 3600} = 0.0886 \approx 0.09$

Money consumed = 0.09 Rs = 9 paise.

11. P = 100 w $\qquad$ V = 220 v

Case I : Excess power = 100 – 40 = 60 w

Power converted to light = $\dfrac{60 \times 60}{100} = 36$ w

Case II : Power = $\dfrac{(220)^2}{484} = 82.64$ w

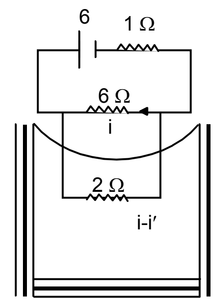
Excess power = 82.64 – 40 = 42.64 w

Power converted to light = $42.64 \times \dfrac{60}{100} = 25.584$ w

$\Delta P = 36 - 25.584 = 10.416$

Required % = $\frac{10.416}{36} \times 100 = 28.93 \approx 29\%$

12. $R_{eff} = \frac{12}{8} + 1 = \frac{5}{2}$ $\quad i = \frac{6}{(5/2)} = \frac{12}{5}$ Amp.



$i' \, 6 = (i - i')2 \Rightarrow i' \, 6 = \frac{12}{5} \times 2 - 2i$

$8i' = \frac{24}{5} \Rightarrow i' = \frac{24}{5 \times 8} = \frac{3}{5}$ Amp

$i - i' = \frac{12}{5} - \frac{3}{5} = \frac{9}{5}$ Amp

(a) Heat = $i^2 RT = \frac{9}{5} \times \frac{9}{5} \times 2 \times 15 \times 60 = 5832$

2000 J of heat raises the temp. by 1K

5832 J of heat raises the temp. by 2.916K.

(b) When 6Ω resistor get burnt $R_{eff} = 1 + 2 = 3\ \Omega$

$i = \frac{6}{3} = 2$ Amp.

Heat = 2 × 2 × 2 ×15 × 60 = 7200 J

2000 J raises the temp. by 1K

7200 J raises the temp by 3.6k

13. $\theta = 0.001°C$ $\quad a = -46 \times 10^{-6}$ v/deg, $\quad b = -0.48 \times 10^{-6}$ v/deg^2

Emf = $a_{BlAg}\,\theta + (1/2)\, b_{BlAg}\,\theta^2 = -46 \times 10^{-6} \times 0.001 - (1/2) \times 0.48 \times 10^{-6} (0.001)^2$

$= -46 \times 10^{-9} - 0.24 \times 10^{-12} = -46.00024 \times 10^{-9} = -4.6 \times 10^{-8}$ V

14. $E = a_{AB}\theta + b_{AB}\theta^2$ $\quad a_{CuAg} = a_{CuPb} - b_{AgPb} = 2.76 - 2.5 = 0.26\ \mu v/°C$

$b_{CuAg} = b_{CuPb} - b_{AgPb} = 0.012 - 0.012\ \mu vc = 0$

$E = a_{AB}\theta = (0.26 \times 40)\ \mu V = 1.04 \times 10^{-5}$ V

15. $\theta = 0°C$

$a_{Cu,Fe} = a_{Cu,Pb} - a_{Fe,Pb} = 2.76 - 16.6 = -13.8\ \mu v/°C$

$B_{Cu,Fe} = b_{Cu,Pb} - b_{Fe,Pb} = 0.012 + 0.030 = 0.042\ \mu v/°C^2$

Neutral temp. on $-\frac{a}{b} = \frac{13.8}{0.042}$ °C = 328.57°C

16. (a) 1eq. mass of the substance requires 96500 coulombs

Since the element is monoatomic, thus eq. mass = mol. Mass

6.023×10^{23} atoms require 96500 C

1 atoms require $\frac{96500}{6.023 \times 10^{23}}$ C = 1.6×10^{-19} C

(b) Since the element is diatomic eq.mass = (1/2) mol.mass

$\therefore$ (1/2) × 6.023 × 10^{23} atoms 2eq. 96500 C

$\Rightarrow$ 1 atom require = $\frac{96500 \times 2}{6.023 \times 10^{23}} = 3.2 \times 10^{-19}$ C

17. At Wt. At = 107.9 g/mole

I = 0.500 A

E_{Ag} = 107.9 g [As Ag is monoatomic]

$Z_{Ag} = \frac{E}{f} = \frac{107.9}{96500} = 0.001118$

M = Zit = 0.001118 × 0.5 × 3600 = 2.01

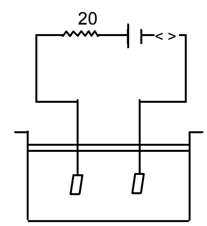
18. t = 3 min = 180 sec   w = 2 g
E.C.E = 1.12×10^{-6} kg/c
$\Rightarrow 3 \times 10^{-3} = 1.12 \times 10^{-6} \times i \times 180$
$$\Rightarrow i = \frac{3\times10^{-3}}{1.12\times10^{-6}\times180} = \frac{1}{6.72}\times10^{2} \approx 15 \text{ Amp.}$$

19. $\frac{H_2}{22.4L} \rightarrow 2g$ $1L \rightarrow \frac{2}{22.4}$
m = Zit $\frac{2}{22.4} = \frac{1}{96500}\times5\times T \Rightarrow T = \frac{2}{22.4}\times\frac{96500}{5}$ = 1732.21 sec ≈ 28.7 min ≈ 29 min.

20. w_1 = Zit $\Rightarrow 1 = \frac{mm}{3\times96500}\times2\times1.5\times3600 \Rightarrow mm = \frac{3\times96500}{2\times1.5\times3600}$ = 26.8 g/mole
$$\frac{E_1}{E_2} = \frac{w_1}{w_2} \Rightarrow \frac{107.9}{\left(\frac{mm}{3}\right)} = \frac{w_1}{1} \Rightarrow w_1 = \frac{107.9\times3}{26.8} = 12.1 \text{ gm}$$

21. I = 15 A   Surface area = 200 cm^2 ,   Thickness = 0.1 mm
Volume of Ag deposited = 200 × 0.01 = 2 cm^3 for one side
For both sides, Mass of Ag = 4 × 10.5 = 42 g
$Z_{Ag} = \frac{E}{F} = \frac{107.9}{96500}$ m = ZIT
$$\Rightarrow 42 = \frac{107.9}{96500}\times15\times T \Rightarrow T = \frac{42\times96500}{107.9\times15} = 2504.17 \text{ sec} = 41.73 \text{ min} \approx 42 \text{ min}$$

22. w = Zit



$$2.68 = \frac{107.9}{96500}\times i\times10\times60$$
$$\Rightarrow I = \frac{2.68\times965}{107.9\times6} = 3.99 \approx 4 \text{ Amp}$$
Heat developed in the 20 Ω resister = $(4)^2 \times 20 \times 10 \times 60$ = 192000 J = 192 KJ

23. For potential drop, t = 30 min = 180 sec
$V_i = V_f + iR \Rightarrow 12 = 10 + 2i \Rightarrow i = 1$ Amp
$$m = Zit = \frac{107.9}{96500}\times1\times30\times60 = 2.01 \text{ g} \approx 2 \text{ g}$$

24. A= 10 $cm^2 \times 10^{-4} cm^2$
t = 10m = 10×10^{-6}
Volume = A(2t) = $10 \times 10^{-4} \times 2 \times 10 \times 10^{-6} = 2 \times 10^{2} \times 10^{-10} = 2 \times 10^{-8}$ m^3
Mass = $2 \times 10^{-8} \times 9000 = 18 \times 10^{-5}$ kg
W = Z × C $\Rightarrow 18 \times 10^{-5} = 3 \times 10^{-7} \times C$
$$\Rightarrow q = \frac{18\times10^{-5}}{3\times10^{-7}} = 6 \times 10^{2}$$
$$V = \frac{W}{q} = \Rightarrow W = Vq = 12 \times 6 \times 10^{2} = 76 \times 10^{2} = 7.6 \text{ KJ}$$

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