Questions and Answers

1. Discuss the following battery characteristics:

a) Cycle life b) Current c) Capacity d) Energy density e) Electricity Electrical storage density.

Answer:
(a) Cycle life: Primary batteries are designed for single discharge, but a secondary battery is rechargeable.
The cycle life is the number of charge/discharge cycles that are possible before failure occurs.
Reasons for failure to achieve high cycle life is,
1. Corrosion at contact points.
2. Shedding of active material from the plates. [Loss of electro active materials from the electrode due to rapid charging conditions]
3. Shorting between electrodes due to irregular crystal growth and changes in morphology.
4. Loss of electro active material from the electrode due to rapid charging conditions.

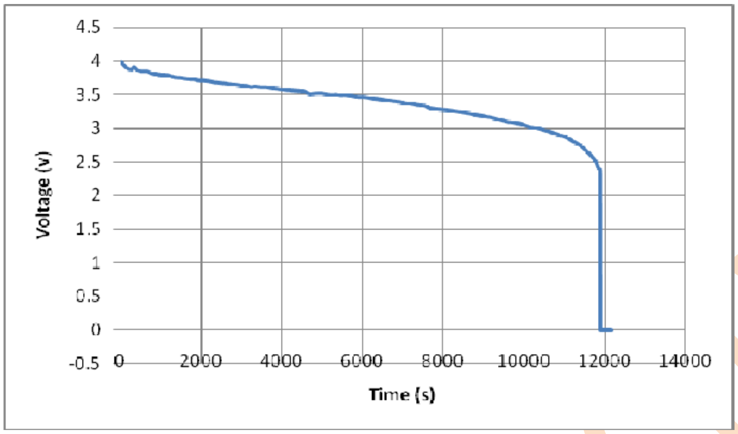
(b) Current: It is the measure of the rate at which battery is discharging. To construct efficient battery large quantity of active materials must be maintained for rapid electron transfer without any excessive voltage penalty. More the electro active materials packed in the cell more is the current generated.
It depends on conductivity of electrolyte. With increase in electrolyte concentration, conductivity of electrolyte increases. The resistance decreases and hence current increases.
Current is expressed in ampere (A) this should be include here

(c) Capacity: The capacity is the charge or amount of electricity that may be obtained from the battery and is given in ampere hours (Ah). Capacity depends on size of the battery and is given by Faraday's relation

$$C=\frac{wnF}{M}$$

where w is the mass and M is the molar mass of active material.
The amount of the active material actually consumed during discharge determines the capacity of the battery. The capacity also depends on the discharge conditions. It is measured by finding the time 't' taken for the battery to reach a minimum voltage for a fixed current discharge (i amperes). The cell is said to be dead at minimum voltage.
Plot of time against voltage at a fixed current discharge is shown in the figure.

The length of the flat portion of the curve is a measure of the capacity of the battery; longer the flat portion better is the capacity.



(d) Energy density:

It is the ratio of energy available from the battery to its Mass (or volume)

$$\text{Energy density} = \frac{\text{Energy available from the battery}}{\text{Mass of the battery}}$$

$$\text{Energy density} = \frac{\text{i x Ecell}}{\text{W}} \text{x t}$$

Where W is mass of the battery, i and E_{cell} are current and EMF generated in the cell, t is time.

The unit of energy density is $Whkg^{-1}$

A cell with a good energy density is preferred.

(e) Electricity Storage density: It is the amount of electricity per unit weight which the storer can hold. In other words, it is the capacity per unit mass of the battery.

The weight of the battery includes weight of electrodes, electrolyte, terminals, case and current collectors. To get high electricity storage density, weight of all the elements should be minimum. For example, 7 g of lithium is required at anode to give 96500 C of charge whereas for the same charge 65 g of zinc is required.

2. Discuss the construction and working of Zn-air battery.

Zinc-air battery is a type of metal-air batteries, which uses oxygen directly from the atmosphere to produce electrochemical energy. Oxygen diffused into the cell and is used as the cathode reactant. The air cathode catalytically promotes the reaction of oxygen with an alkaline electrolyte and is not consumed or changed during discharge. As the cathode can be very compact, high energy densities are achieved.

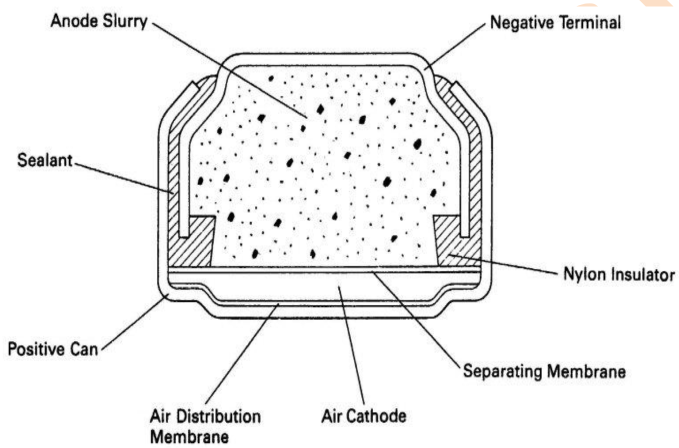
Construction:

Anode: Loose powdered zinc with an aqueous alkaline electrolyte and gelling agent (to immobilize the composite and ensure adequate contact with zinc granules).

Cathode: Amorphous carbon (graphite) blended with MnO_2 (catalyst) coated on nickel wire mesh.

Electrolyte: 30 % KOH

Separator: Polypropylene membrane soaked in electrolyte.



Anode : $Zn \longrightarrow Zn^{2+} + 2e^-$

$Zn^{2+} + 2OH^- \longrightarrow ZnO + H_2O$

$Zn + 2OH^- \longrightarrow ZnO + H_2O + 2e^-$

Cathode : $1/2O_2 + H_2O + 2e^- \longrightarrow 2OH^-$

Overall reaction : $Zn + 1/2O_2 \longrightarrow ZnO$

3. a) Why does Mg-AgCl Reserve battery has high Shelf life?
   b) Give construction and working of Mg-AgCl reserve battery.

Answer:

a) In reserve battery, one of the key components like electrolyte is kept separated from the rest of the battery. Hence Mg-AgCl Reserve battery has long shelf life.

b) **Construction:**

Anode (Negative Plate): Magnesium sheet.

Cathode (Positive Plate): Silver chloride sheets covered with silver on the surface by reduction to make conducting electrode surface.

Separators: Woven or nonwoven fabric, absorbent, nonconductive material is utilized for the dual purpose of separating the electrodes and absorbing the electrolyte.

Electrolyte: water or sea water

Working:

$$\text{Anode: } Mg \longrightarrow Mg^{2+} + 2e^-$$

$$\text{Cathode: } 2AgCl + 2e^- \longrightarrow 2Ag + 2Cl^-$$

$$\text{Overall reaction: } Mg + 2AgCl \longrightarrow MgCl_2 + 2Ag$$

4. With the help of a neat diagram, explain the construction and working of CH_3OH CH_3-O_2 Polymer membrane fuel cell.

Answer:

Direct-methanol fuel cells or DMFCs are a subcategory of proton-exchange fuel cells in which methanol is used as the fuel. Their main advantage is the ease of transport of methanol, an energy-dense yet reasonably stable liquid at all environmental conditions.

Whilst the thermodynamic theoretical energy conversion efficiency of a DMFC is 97 %; the currently achievable energy conversion efficiency for operational cells attains 30 % - 40 %.

DMFCs use a methanol solution (usually around 1M, i.e. about 3% in mass) to carry the reactant into the cell; common operating temperatures are in the range 50–120 °C, where high temperatures are usually pressurized.

Construction:

Anode: Platinum

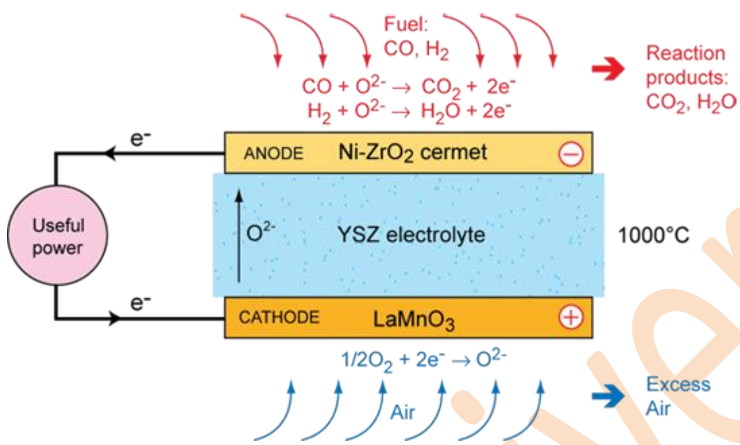
Cathode: Platinum

Fuel: Methanol

Oxidant: Oxygen gas

Electrolyte: This uses a polymer membrane as its electrolyte. This membrane is an electronic insulator but an excellent conductor of H^+ ions. E.g. : Nafion

Nafion: This polymer consists of fluorocarbon backbone ($–CF_2$-CF_2-) similar to teflon to which sulphonic acid groups are attached. The protons on sulphonic acid group are free to migrate through the hydrated membrane.



At Anode : $CO + O^{2-} \longrightarrow CO_2 + 2e^-$

At Cathode : $1/2O_2 + 2e^- \longrightarrow O^{2-}$

Over all reaction : $CO + 1/2O_2 \longrightarrow CO_2$

5. Define fuel cell? Calculate the efficiency of H_2-0_2 alkaline fuel cell [EmfE^0=1.28V, ΔH^0=-285.8 KJ/mole

Answer: A fuel cell is a galvanic cell which converts chemical energy of a fuel oxidant system directly into electrical energy by means of redox reaction or electrochemical reactions.

$$\eta = \frac{\Delta G}{\Delta H} \text{ x } 100 = \frac{-nFE}{\Delta H} \text{ x } 100 = \frac{-2 \text{ x } 96500 \text{ x } 1.23}{-285.8 \text{ x } ?\,(1000)} \text{ x } 100 = 83.06\ \%$$

6. With a neat labeled diagram explain the construction and working of a super capacitor.

Answer: Super Capacitors, ultra capacitors or electrochemical double-layer capacitors are devices that can be used as storage systems, that have high energy densities, a high energy efficiency, nearly 95 % and a large life expectancy.

Construction:

EDLCs consist of two electrodes in contact with an electrolyte like KOH.

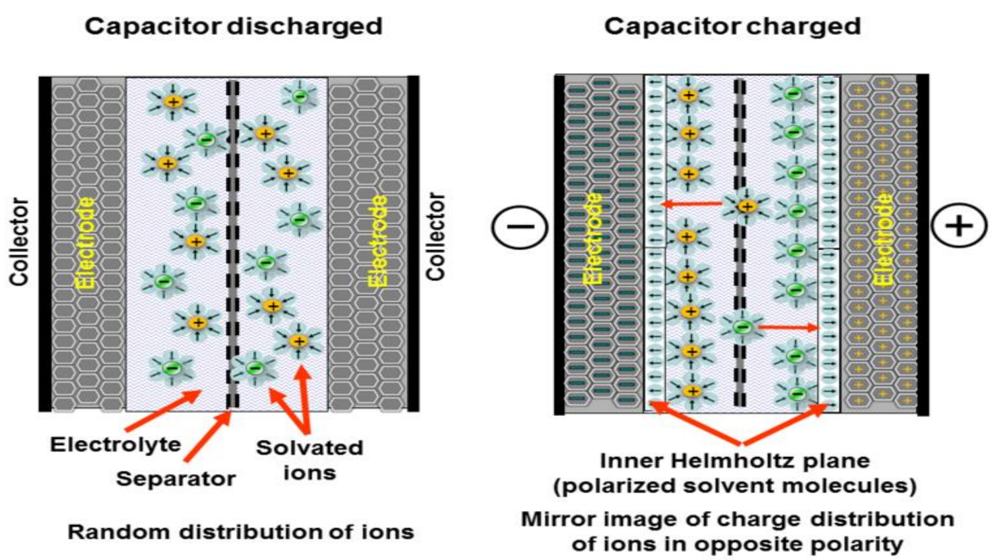
An ion permeable separator is placed between the electrodes in order prevent electrical contact, but still allows ions from electrolyte to pass through.

The electrodes are made up of high surface area materials such as porous carbon, graphene, carbon nanotubes and certain conducting polymers or carbon aerogel.

Working:

The applied potential on the positive electrode attracts the negative ions in the electrolyte, while negative electrode attracts the positive ions. This results in the formation of electrical double layer at entire electrode /electrolyte interface. Thus EDLCs store large amount of charges.

Unlike in a battery, the positive and negative charges in a supercapacitors are produced entirely by static electricity; no chemical reactions are involved.



7. Calculate the energy density of zinc- air battery in Whr/Kg, if 5.6 g of Zn is stored in the battery and the weight of the battery is 25.5 g. [Given : voltage of Zn-air battery = 1.3 V, molar mass of Zn = 65.38)

Answer:

$$C = \frac{WnF}{M} = \frac{5.6 \times 2 \times 96500}{65.38 \times 3600} = 4.591 \text{ Ah}$$

$$\text{Energy density} = \frac{\text{C x Ecell}}{\text{W}} = \frac{4.591 \times 1.3}{25.5 \text{ x } 10^{-3}} = 234.05 \text{ Whr/kg}$$