1) Pb-Ca (0.1%) as the anode which inhibits the electrolysis of water.

2) a catalyst (eg. a mixture of 98% ceria (cerium oxide) & 2% Pt that combines the H_2 & O_2 produced during discharge back into water.

11/11 NICKEL-CADMIUM CELL

ANODE: Spongy Cd

CATHODE: $Ni(OH)_3$ mixed with 20% graphite powder

ELECTROLYTE: conc soln of KOH (compatibility with various electrodes, good conductivity & low f.p) 20-28% KOH.

SEPARATOR: Thin plastic pins/ Layers of cellulose felt.

CONTAINER: Steel case.

CELL SCHEME: $Cd / Cd(OH)_2, KOH, Ni(OH)_2 / Ni$

O.C.V = 1.25 V.

WORKING:

Discharging.

Anode: $Cd_{(s)} + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$

Cathode: $2Ni(OH)_3 + 2e^- \rightarrow 2Ni(OH)_2(s) + 2OH^-(aq)$

$$Cd_{(s)} + 2Ni(OH)_{3(s)} + 2H_2O \rightarrow 2Ni(OH)_2(s) + Cd(OH)_2(s)$$

Charging reactions:

Anode:

$Cd(OH)_{2(s)} + 2e^- \longrightarrow Cd_{(s)} + 2OH^-_{(aq)}$

Cathode:

$2Ni(OH)_{2(s)} + 2OH^-_{(aq)} \longrightarrow 2Ni(OH)_{3(s)} + 2e^-$

Net:

$2Ni(OH)_{2(s)} + Cd(OH)_{2(s)} \longrightarrow 2Ni(OH)_{3(s)} + Cd_{(s)}$

Concentration of electrolyte does not change.

ADVANTAGES:

- Long cycle life
- Constant voltage 1.25 V
- Long shelf life
- No gassing
- Long design life.
- Good performance at low temp.
- Produce large current (instantaneous)

DISADVANTAGES.

- Environmental pollution hazard.
- Increased weight
- High overall cost
- KOH is a corrosive hazardous chemical

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LITHIUM - ION - CELLS

Cathode: lithiated Transition metal oxides are inserted. eg ($LiCoO_2$), (LiV_2O_5)

Anode: made up of graphite in to which lithium ion is intercalated

Seperators: polyolefin's (PP/PE/PP or just PE) using 3 to 8 μm layers with 50% porosity.

Electrolyte: 1M solution of a lithium salt in an organic solvent.

eg 1) Lithium hexafluorophosphate ($LiPF_6$) in the solvent propylene carbonate.

2) Lithium tetrafluoroborate ($LiBF_4$) in a solvent ethy lene carbonate.

Lithium metal is never used in Li-ion cells. It works based on the swing effect

DISCHARGE REACTION.

The main principle is based on the movement of lithium ions between anode and cathode through the electrolyte occurs during discharge.

Anode: $Li(C) \longrightarrow Li^+ + e^-$

Cathode: $Li^+ + e^- + CoO_2 \longrightarrow LiCoO_2$

The overall reaction.

$$CoO_2 + Li(C) \longrightarrow LiCoO_2$$

CHARGING.

$$LiCoO_2 \longrightarrow Li^+ + e^- + CoO_2,$$
$$Li^+ + e^- \longrightarrow Li(C)$$

$LiCoO_2$ +

ADVANTAGES.

- Designed to overcome safety problems
- Long cycle life.
- Small light & provide high energy density.
- Can be operated in a wide temp range (Good at low temps)
- High average voltage
- Li highest oxidation potential
- High energy density due to low stoichiometric mass.

DISADVANTAGES

- Poor charge retention
- Self discharge rate is about 10% per month
- High cost.

APPICATIONS-

- Laptops, telephones, camrecorders etc.

FUEL CELLS

A fuel cell is a galvanic cell in which chemical energy of a fuel-oxidant system is converted directly into electrical energy in a continuous-electrochemical process.

Scheme:

Fuel ; electrode / electrolyte / electrode / oxidant.

- The reactants (ie fuel + oxidant) are constantly supplied from outside and products are removed at the same rate.

Anode:

Fuel + Oxygen → Oxidation products + ne^-

Cathode.

Oxidant + ne^- → Reduction products.

REQUIREMENTS.

- Electrodes: Must be stable porous and a good conductor.
- Catalyst: Porous electrode must be impregnated with catalyst like Pt, Pd, Ag or Ni to enhance otherwise slow reactions.
- Temperature: Optimum
- Electrolyte: Fairly concentrated.

ADVANTAGES.

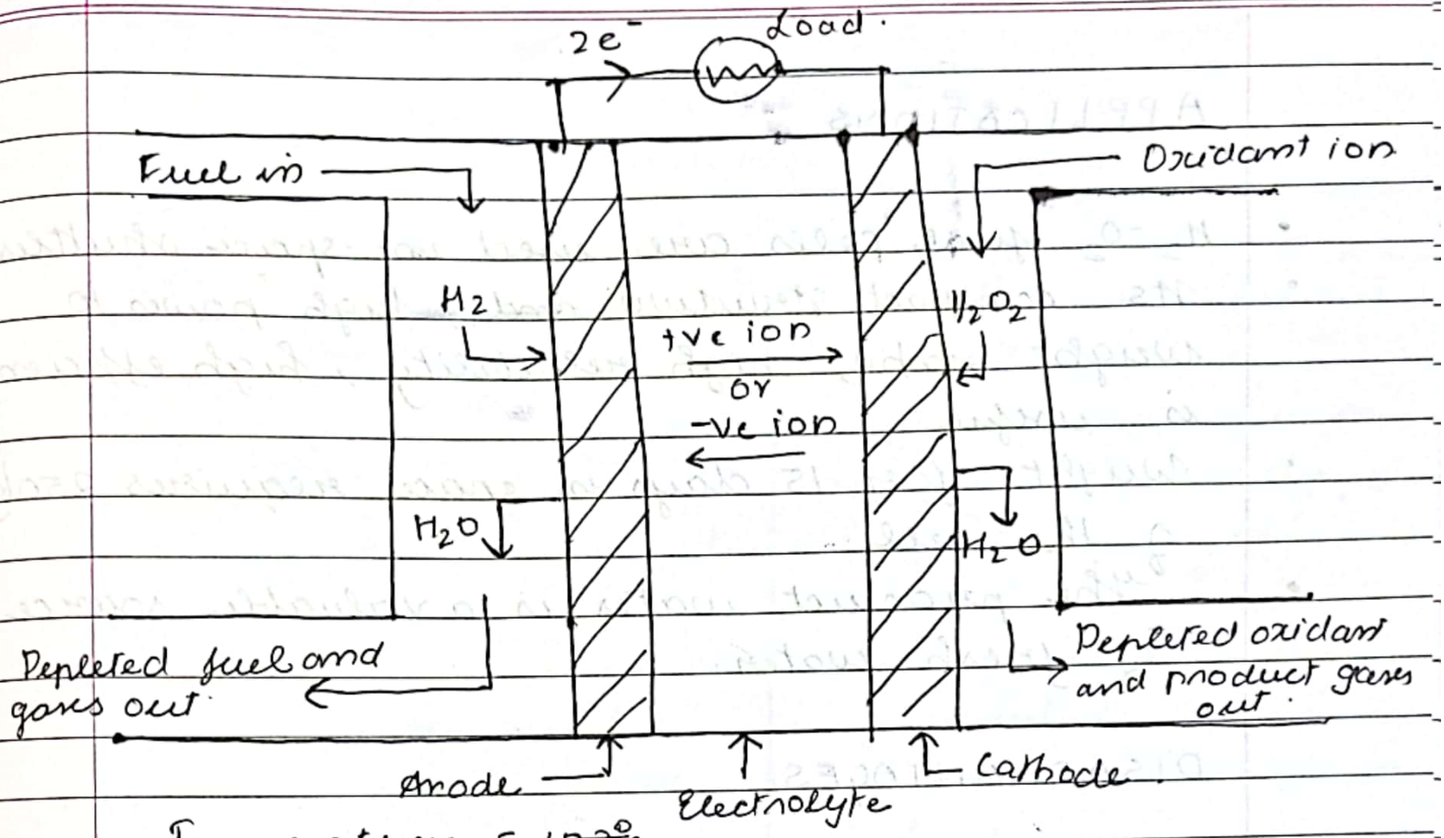
- High efficieny of the energy conversion process
- Silent process.
- No moving parts and so elimination of wear and tear.
- Absence of harmful waste products.
- No need of charging

APPLICATIONS

- Used as energy source in space shuttles.
- Used in small scale applications in submarines and other military vehicles.
- Suitable in places where environmental pollution and noise are objectionable.

LIMITATIONS.

- Cost of power is high as result of the cost of electrodes and catalysts.
- Fuels in the form of gases and O_2 need to be stored in tanks under high pressure.
- Power output is moderate.
- They are sensitive to fuel contaminants such as CO, H_2S, NH_3 & halides depending on the fuel cell.



~~Temperature = 100°C~~

HYDROGEN CELL

Anode: Porous graphite electrodes impregnated with finely divided Ni or Pt/Pd.

Cathode: Porous graphite electrodes impregnated with finelly divided NiO or Pt/Pd.

Electrolyte: 35-50% KOH held in ~~abb~~ asbestos matrix.

Operating temp: 90°C.

Reactions: (water must be removed from the cell and O_2 must be pure)

Anode: $2H_2 \longrightarrow 4H^+ + 4e^-$

$4H^+ + 4OH^- \longrightarrow 4H_2O$

Net: $2H_{2(g)} + 4OH^- \longrightarrow 4H_2O_{(l)} + 4e^-$

Cathode: $O_{2(g)} + 2H_2O_{(l)} + 4e^- \longrightarrow 4OH^-_{(aq)}$

Net Reaction:

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

APPLICATIONS

- H_2-O_2 fuel cells are used in space shuttles.
- Its compact structure and, high power to weight ratio, high reliability, high efficiency is useful.
- Weight: for 15 days in space requires 250kg of the cell.
- The product water is a valuable source of fresh water.

DISADVANTAGES.

- Degradation or malfunction of components limits practical operating life.
- High initial cost because of noble metals.

CH_3OH-O_2 FUEL CELL

- Both electrodes: Made of pourous Ni plate impregnated with finely divided Pt.
- Fuel: methyl alcohol
- Oxidant: Pure oxygen/air.
- Electrolyte: Conc. phosphoric acid / Aq KOH.
- Operating Temperature: 150-200°C.

EMF = 1.20 V.

MeOH is one of the most electroactive organic fuels in

DIFFERENCES

Galvanic Cells.	Fuel Cells.
• Stores chemical energy	• Does not store chemical energy
• The reactants form an integral part of it	• Reactants are fed from outside continuously.
• These conditions are not required.	• Need expensive noble catalysts.
• Pollutants are generated after their useful life.	• No pollutants are generated.
• Cannot produce power from fuels	• Produces power from fuels.
• Limited life span in use.	• Never becomes dead.
• Useful as portable power supplies	• Useful for long term electricity generation.
• No problem of removal of reaction products.	• ~~Px.~~ Reaction products must be continuously removed.

~~Ro~~ Proton Membrane

$$-\!\left(CF_2-CF_2\right)_n CF_2 - CF_2 - \underset{\displaystyle |\atop \displaystyle O - CF_2 - CF_2 - SO_3H^{(+)}}{CF}\,.$$

$$2H_2 + 4H_2O \rightarrow 4H_3O^+ + 4e^-$$

$$O_2 + 4H_3O^+ + 4e^- \longrightarrow 6H_2O.$$

It requires critical water management because rate of formation of water is greater than rate of removal.