Unit: III Electrochemical Cells (ECE)

FUEL CELL: In fuel cell electrical energy is obtained without combustion from O_2 and a gas that can be oxidized, Hence, a fuel cell converts the chemical energy of the fuels directly to electricity or electrical energy.

The essential process in a fuel cell is:

Fuel + O_2 ⟶ oxidation product + Electricity

✓Fuel cells are based on redox (oxidation-reduction) reaction that lead to generate electrical energy.

Example: H_2–O_2 Fuel cell

H_2–O_2 Fuel cell consists of an electrolytic solution (such as 25% KOH or NaOH and two inert porous electrodes (i.e Anode and cathode). H_2 and O_2 gases are bubbled through the anode and cathode compartment respectively. where the following reactions take place

Anode $2H_{2(g)} + 4OH^-_{(aq)} \longrightarrow 4H_2O_{(l)} + 4e^-$

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

Net Rxn. is $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

The standard EMF of the cell

$$E^\circ = E^\circ_{oxd} + E^\circ_{red} = 0.83V + 0.40V = 1.23V$$

In practice, the EMF of cell is 0.8 to 1.0 volt. It may be noted that the only product discharged by the fuel cell is water. A large number of these cells are stacked together in a series to make a battery called as fuel cell battery or Fuel battery

Electrodes to be used for fuel cell must be (1) Good conductors (2) Good electron sources or sink (3) not be consumed or deteriorated or decayed by the electrolyte heat or electrode reactions.

Moreover, the electrodes must be excellent catalysts for the reactions

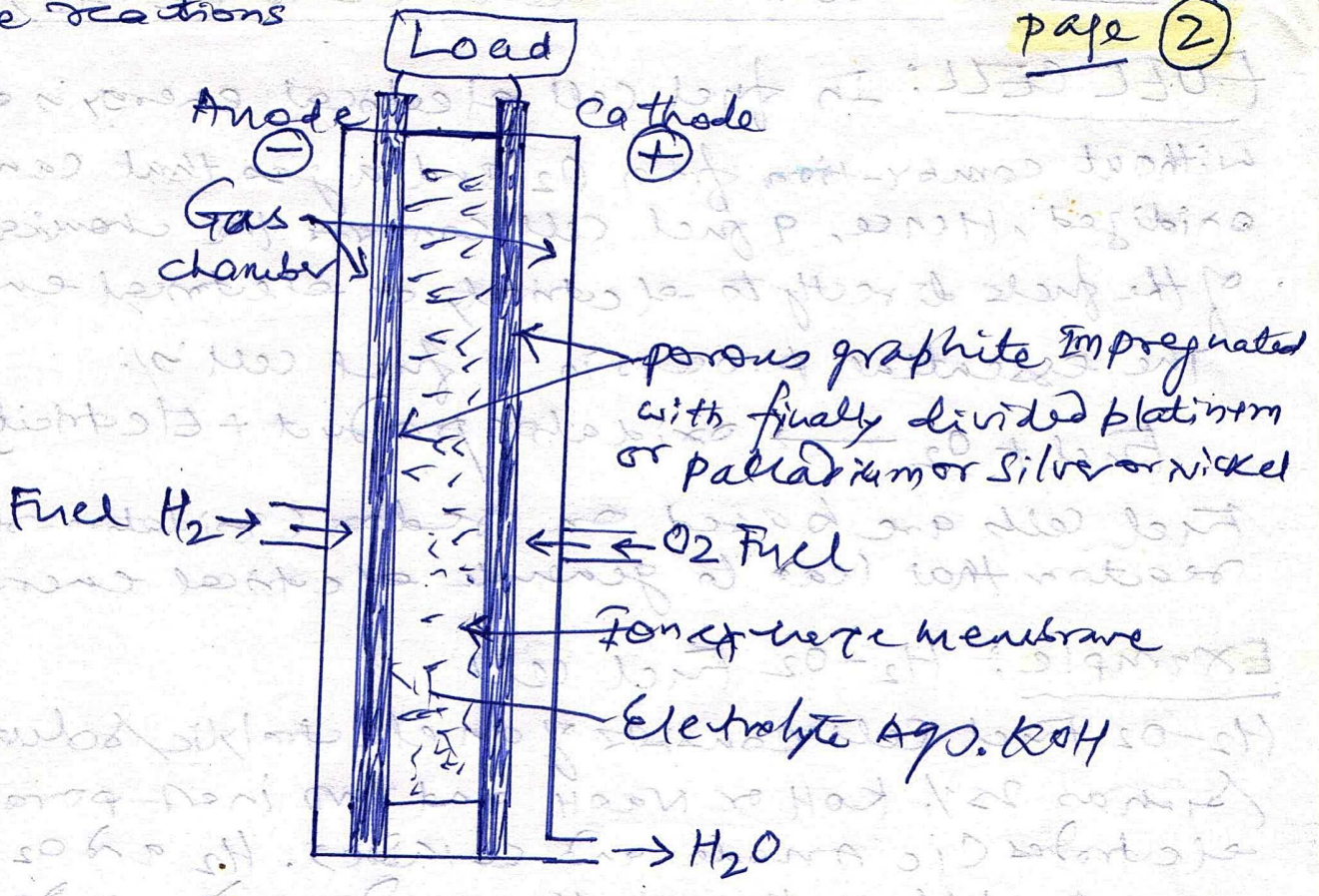

Fig: H_2–O_2 Fuel cell

Application: H_2–O_2 fuel cell are used as auxillary energy source in space vehicles eg. Apollo spacecraft, submarines or other military vehicles. The weight of fuel battery is 250 kg approx. In case of H_2–O_2 fuel cell the product water proved to be a valuable source of fresh water by the astronauts.

Other fuel cells

① propane–oxygen fuel cell C_3H_8–O_2 Fuel cell

Anode: $C_3H_8(g) + 6H_2O(l) \rightarrow 3CO_2(g) + 20H^+_{(Aq)} + 20e^-$

Cathode: $5O_2(g) + 20H^+_{(Aq)} + 20e^- \rightarrow 10H_2O(l)$

Net Rxn. is $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

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(2) $CH_3OH - O_2$ Fuel cell:

Anode: $CH_3OH_{(l)} + H_2O_{(l)} \rightarrow CO_{2(g)} + 6H^+_{(Aq)} + 6e^-$

Cathode: $3/2\ O_{2(g)} + 6H^+_{(Aq)} + 6e^- \rightarrow 3H_2O_{(l)}$

Net Rxn. is $CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

(3) Phosphoric Acid Fuel cell: First generation fuel cell

Liquid phosphoric acid as electrolyte. Electrodes are made up of carbon paper coated with finely dispersed platinum catalyst. Phosphoric Acid Fuel cells are used/operated around 150 to 200°C above the boiling point of water. Efficiency of the cell about 37 to 42%.

(4) Molten carbonate Fuel Cells: are second generation fuel cell designed to operate at higher temperature. Electrolyte is made up of lithium potassium carbonate salts heated to about 650°C. At this temp. the salts melt into molten state that can conduct charged particles called ions between two porous electrodes

Efficiency of the cell is around 60%.

Anode Reaction: $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$

Cathode Reaction: $1/2\ O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$

(5) Solid polymer Electrolyte fuel cell or proton exchange membrane Fuel cell (PEFC). In this cell a polymer membrane used as electrolyte which is an electronic insulator but excellent conductor of Hydrogen ions.

The materials used consists of a fluro carbon polymer backbone similar to Teflon. PEFC operates at about 80°C the water is produced as liquid and is carried out of the fuel cell by excess flow.

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(6) Solid oxide Fuel Cells (SOFC): are composed of all Solid State materials — Anode and cathode and Electrolyte all made from ceramic substances. Because of the all ceramic make up, the cells can operate at high Temp as high as 1000°C

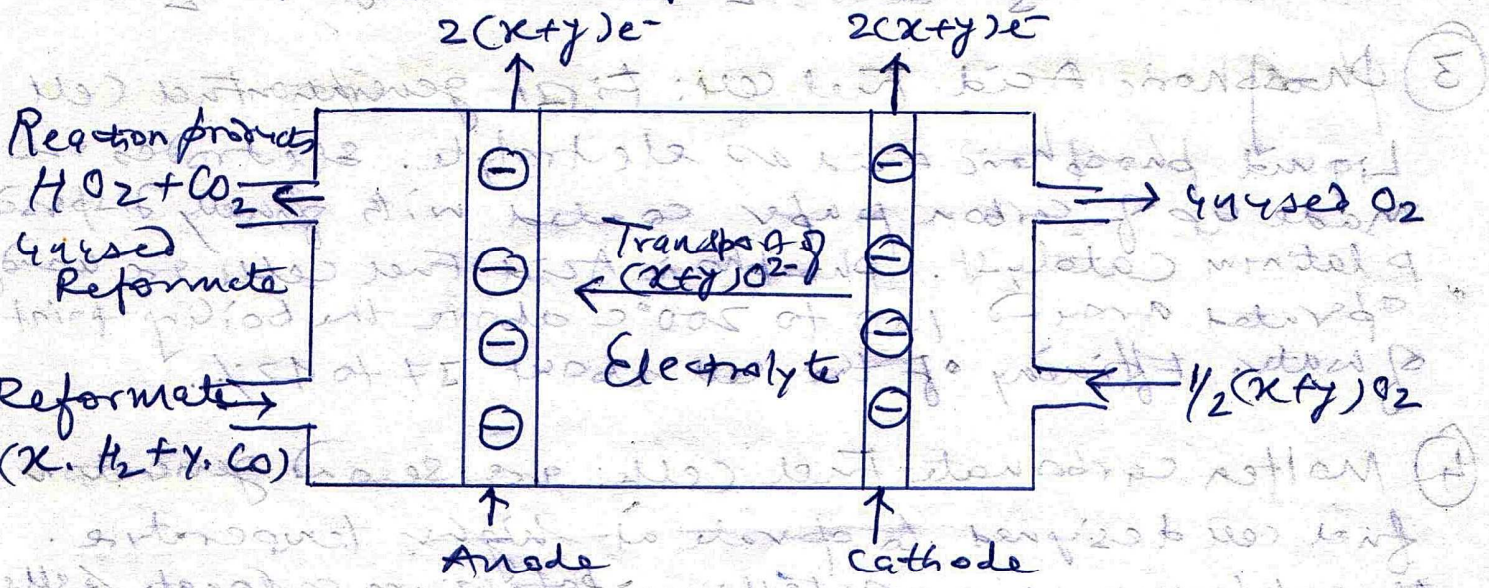

Fig SOFC

Anode Reaction: $xH_{2(g)} + yCO_{(g)} + (x+y)O^{2-} \downarrow$

$xH_2O + yCO_{2(g)} + 2(x+y)e^-$

Cathode Reaction $\frac{1}{2}(x+y)O_{2(g)} + 2(x+y)e^- \longrightarrow (x+y)O^{2-}$

Efficiency of SOFC is around 50%.

(7) Biochemical Fuel Cell (BFC): consits of glucose or urea acts as a fuel (at cathode which is bridged by living organisms (eg. bacteria or enzymes derived from bacteria). These living organisms thus act as bio-anodes. Direct reduction of O_2 (or some other oxidant) at the bioanode is also possible. Biochemical fuel cell produces electricity and at the same time control pollution due to organic wastes.

"Fuel cell do not store chemical energy."