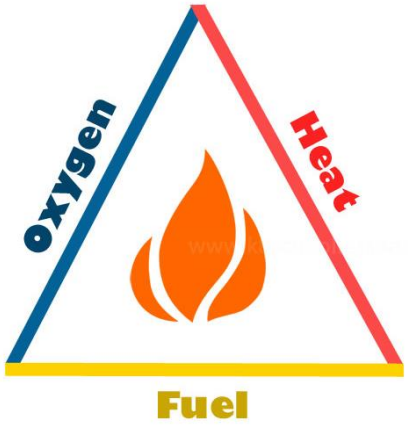
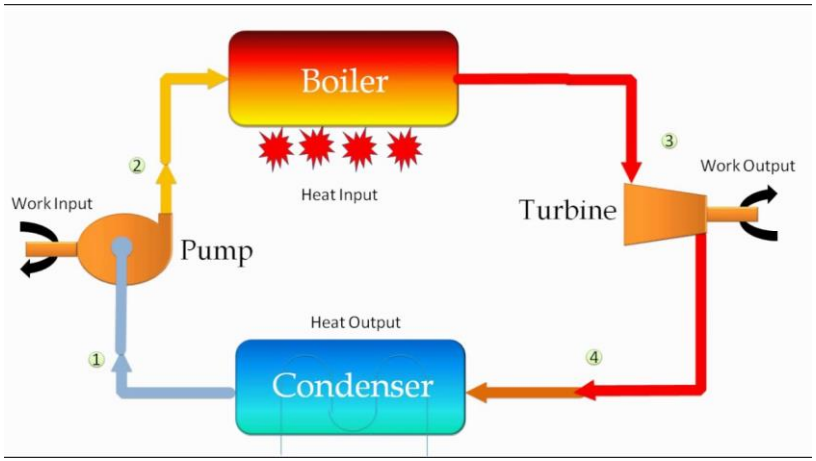
Fuel – Oxidizer reaction

Combustion



Fire Triangle



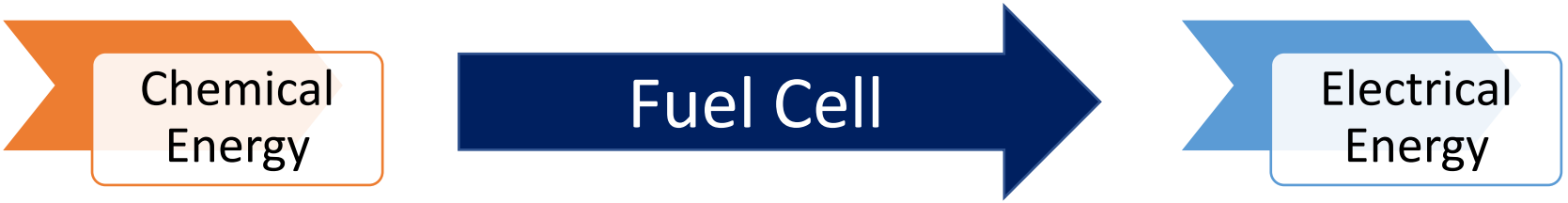
Rankine Cycle

RedOx reaction between Fuel and Oxidizer produces thermal energy → converted in to electrical energy by rankine cycle (Thermal energy → Mechanical energy → Electrical energy)

Fuel Cell

Thermal Power Plants→ Fuel is oxidized to produce thermal energy and it is converted in to mechanical and electrical energy

Fuel cell→ Electrochemical redox reaction of Fuel and Oxidant, directly converts chemical energy in to electrical energy



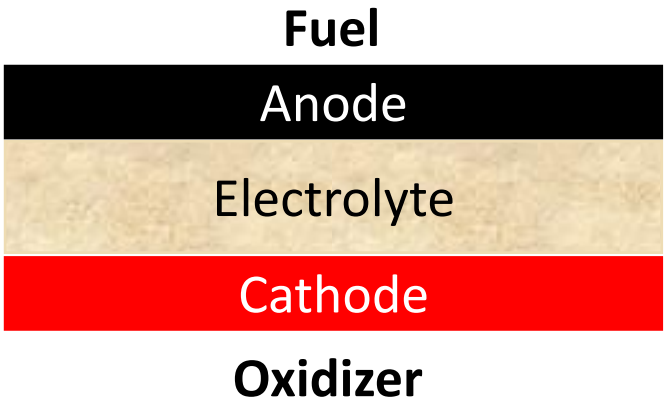
Minimized Interconversion Loss →

Efficient

Fuel Cell

- Electrochemical Cell having a separate fuel-oxidizer system that produces electrical energy by oxidation of Fuel at Anode and the reduction of Oxidizer at Cathode.
- Fuel and Oxidizer are stored outside the battery and supplied as needed.
- Supply of Fuel and Oxidizer → Production of electricity
- High efficiency and Pollution free
- By products are Water and Heat
- Used in NASA Apollo Space Crafts
- e.g. H_2-O_2 Fuel Cell, Solid Oxide Fuel Cell

Fuel Cell Components



- Fuel
- Oxidizer
- Electrodes
  - Anode – Catalyze the oxidation of fuel
  - Cathode – Catalyze the reduction of Oxygen
- Electrolyte
  - Only allows Ions to pass through and blocks electron flow

Fuel / Electrode // Electrolyte // Electrode / Oxidizer

$H_2 - O_2$ Fuel Cell

- Electrolysis of water → Splitting of water produces H_2 and O_2.

  (Electrolytic cell)

Reverse reaction ??

- Combining H_2 and O_2 to produce H_2O

  (Electrochemical Cell)

- Gas Voltaic Battery

Sir William Grove
(invented - 1839)

Fuel Cell Types

- Based on Electrolyte
  - Alkaline Fuel Cell – **KOH**
  - Polymer Membrane Fuel Cell – Polymer electrolyte – **Nafion**
  - Solid Oxide Fuel cell – Oxide electrolyte – Y doped Thoria, Ceria Stabilize Zirconia

Type of Fuel Cell	Electrolyte type	Electrolyte Example	Ions transported	Water formation in
Alkaline	Alkaline	KOH	OH^-	Anode
Polymer Membrane	Proton conducting Polymer	Nafion	H^+	Cathode
Solid Oxide fuel cell	Metal oxide	Y-doped Thoria	O^{2-}	Anode

Alkaline Fuel cell (or) $H_2 – O_2$ Fuel Cell

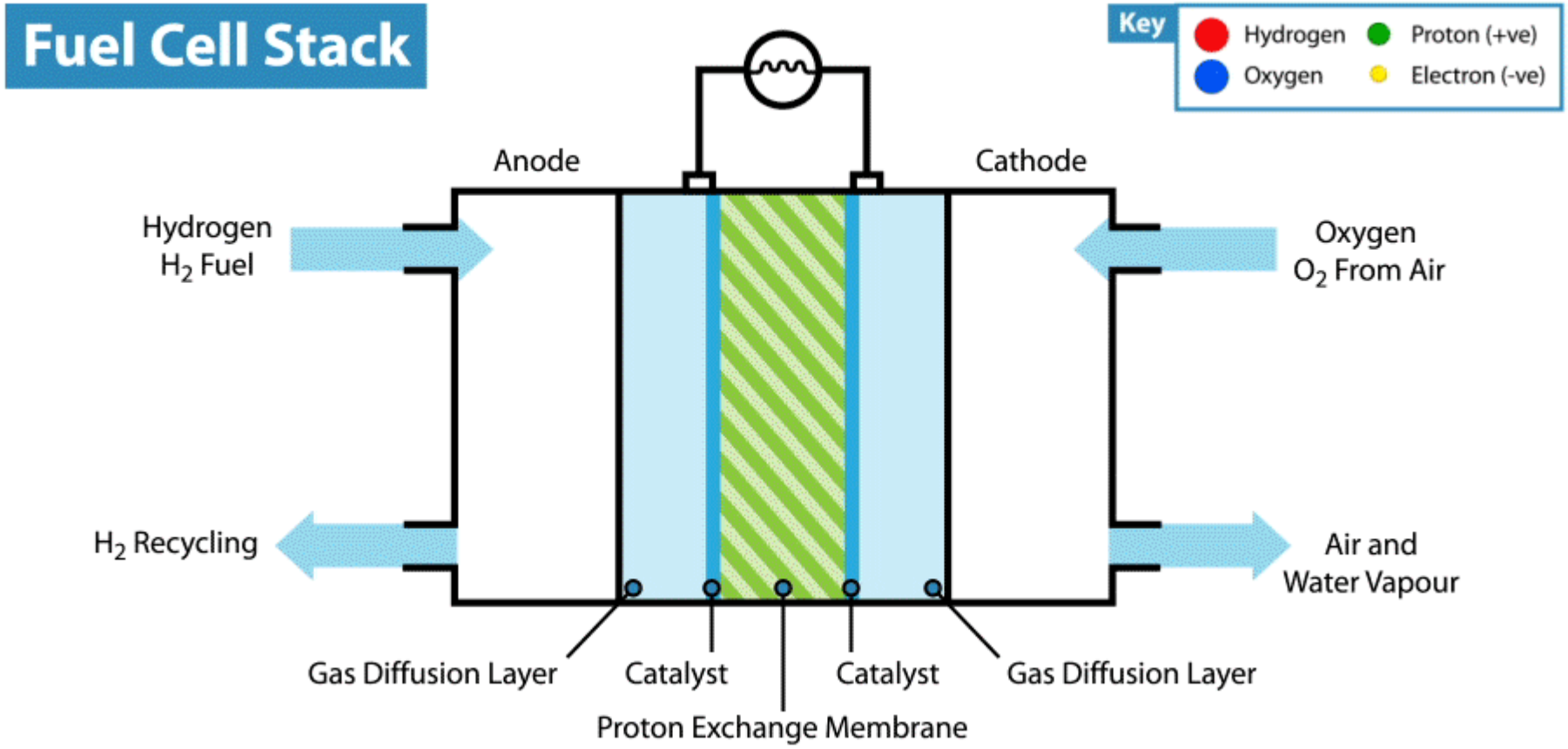
- Fuel – Hydrogen
- Oxidizer – Oxygen
- Electrodes

  Anode – Pt (or) Pd electrode

  Cathode – Pt (or) Ag
- Electrolyte

  KOH

$H_2 - O_2$ Fuel Cell



$H_2 - O_2$ Fuel Cell Reactions

- Anodic reaction

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

- Cathodic Reaction

$$O_2 + 4H_2O + 4e^- \rightarrow 4\ OH^-$$

Net Reaction

$$O_2 + 2H_2 \rightarrow 2H_2O$$

Requirements for Good Fuel Cell

- Electrodes should catalyze the anodic and cathodic reactions
- Fuels should be Pure and Cheap - Hydrogen!!
- Oxidizers used Oxygen or Air → Pure oxygen is preferred

Limitations of Fuel Cell

- Pure Hydrogen…
- Electrode and electrolyte contamination/degradation
- Cost of Catalyst – Pt and Pd !!!
- Safety!!

High temperature → Improved kinetics, low risk of contamination

Materials stable at high temperature is needed

Solid Oxide Fuel Cell (SOFC)

Types of Fuel Cell

Based on the operational temperature

- Low Temperature Fuel Cell – Fuel – Pure Hydrogen (below 100 ^{o}C)
- Mid Temperature Fuel Cell – Fuel – Hydrogen or Reformed Hydrocarbons (100-300 ^{o}C)
- High Temperature Fuel Cell – Fuel – Hydrocarbons, Electrolytes – solid ceramics (~1000 ^{o}C)

Solid Oxide Fuel Cell

- $H_2 – O_2$ Fuel Cell

  H_2 → H^+ diffuses through electrolyte to cathode

- Solid Oxide Fuel Cell

  O_2 → $2O^{2-}$ diffuses through electrolyte to anode

Electrolyte → Good oxide ion conductor and poor electron conductor

- Operates at high temperature so diffusion rate is higher.
- Electrical insulating oxide with non-stoichiometry

e.g. Yttria Stabilized Zirconia (YSZ), Gadolinium Doped Ceria (GDC)

Solid Oxide Fuel Cell (SOFC)

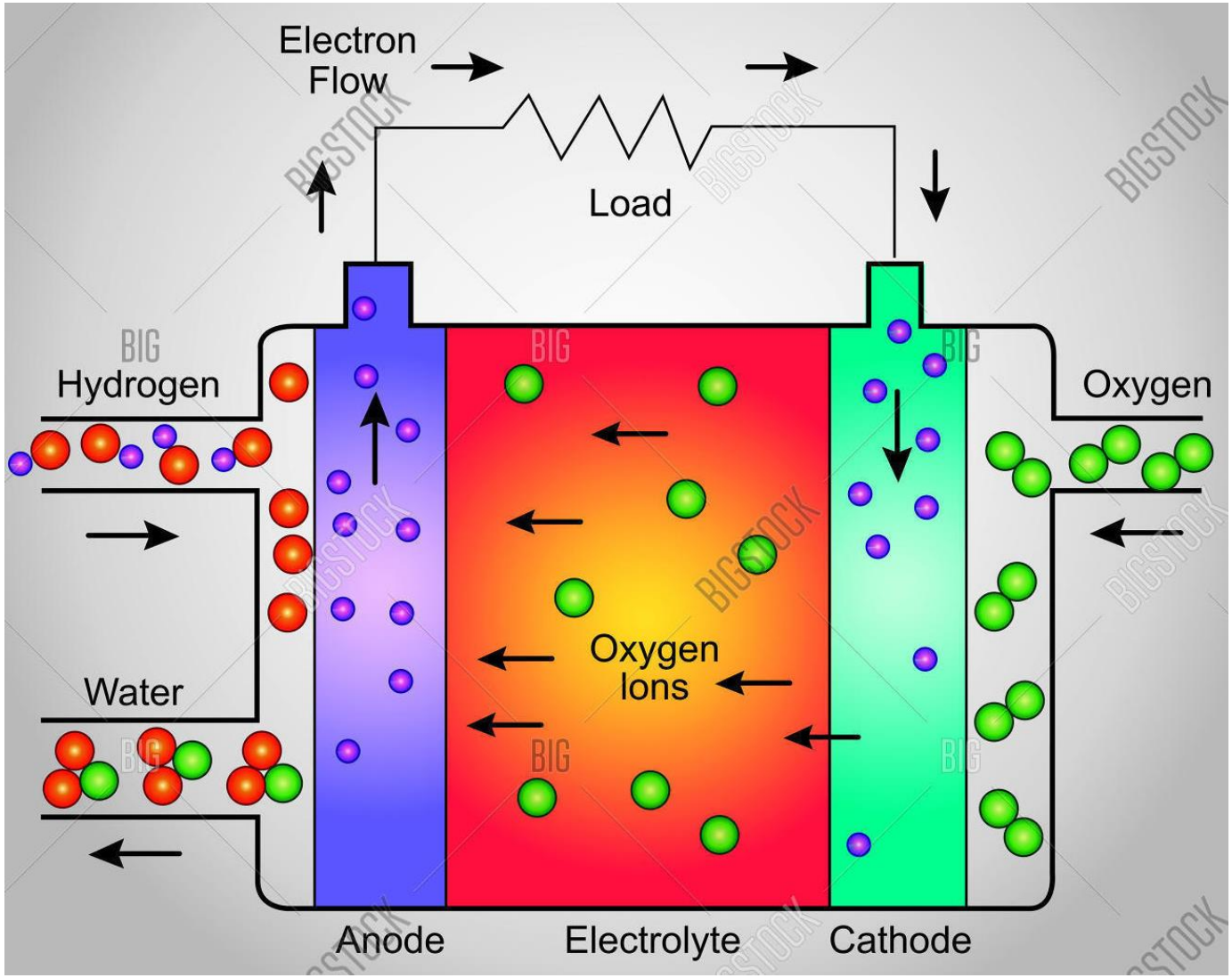
- Fuel – Hydrogen
- Oxidizer – Oxygen
- Electrodes

  Anode – Mixture of Ni and Yttria Stabilized Zirconia (YSZ)

  Cathode – Sr-doped Lanthanum Manganite ($La_{1-x}Sr_xMnO_3$)
- Electrolyte

  Oxide ion conductors (YSZ, GDC)

Solid Oxide Fuel Cell



Solid Oxide Fuel Cells - Reactions

- Anode reaction

$$2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$$

- Cathode Reaction

$$O_2 + 4e^- \rightarrow 2O^{2-}$$

- Net reaction

$$2H_2 + O_2 \rightarrow 2H_2O$$

In $H_2 - O_2$ fuel cell water is formed on cathode side
In SOFC water is formed on anode side.

Advantages of Fuel Cell

- Low maintenance cost
- Silent operation
- Produces pure water as a product
- Heat generated during H_2O formation can also be used
- High energy conversion efficiency
- They can be used as auxiliary power units