

Pretreatment and Activation of the surface:

The plastic board is first degreased using organic solvent. Stainless steel is activated by dipping in 1:1 H_2SO_4 . Magnesium alloys are given a zinc or copper undercoat by electroplating. Non metallic objects like plastic board are activated by dipping in SnCl_2 and then PdCl_2 to get a thin layer of palladium.

Plating bath solution: A solution of NiCl_2 20g /litre,

Reducing agent: Sodium hypophosphate 20g/litre

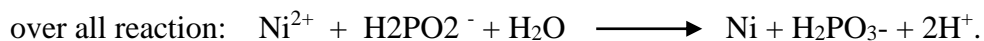
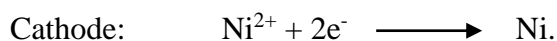
Buffer: Sodium Acetate 10g/lit

Complexing agent: Sodium Succinate.

PH: 4.5

Temperature: 93°C

Reaction:



Uses:

- i) Used to plate on industrial components such as pumps and valves, shafts, gears, reaction vessels and other tools.
- ii) To coat on steel, plastic, PCB's etc.

MODULE- III
ENERGY SYSTEM

Chemical fuels:

Introduction:

“A chemical substance, which produces significant amount of heat and light energy when it is burnt in air or oxygen, is called a chemical fuel. The main constituents of fuel are carbon and hydrogen.”

During the process of combustion of a fuel the atoms of carbon, hydrogen etc. combine with oxygen with the simultaneous liberation of heat at a rapid rate. This energy is liberated due to the rearrangement of valence electrons in the atoms, resulting in the formation of new compounds (like CO₂, H₂O etc.). Since the heat content of combustion products being lower than that of reactants, the chemical fuels release heat during their combustion process.



The primary or main sources of fuels are coal and petroleum oil. These are stored fuels available in earth's crust and are generally called fossil fuels.

Classification of fuels:

Depending on their origin fuels are classified into primary and secondary fuels. These are again classified into solids, liquids and gases, depending on their physical state.

(1) Primary fuels or natural fuels: they are found in nature

| Physical state | Primary fuels | Secondary fuels |
|----------------|---------------|--------------------------|
| Solid | Wood, coal | Charcoal, coke |
| Liquid | Petroleum | Petrol, diesel, kerosene |
| Gas | Natural Gas | LPG |

(2) Secondary fuels: are those that are prepared from the primary fuels.

Characteristics of a good fuel:

The following are the desirable properties of a good chemical fuel.

1. **High calorific value:** A fuel should possess high calorific value, since the amount of heat liberated and temperature attained thereby depends upon the calorific value of fuel.
2. **Moderate ignition temperature:** Ignition temperature is the lowest temperature to which the fuel must be pre heated so that it starts burning smoothly. Low ignition temperature is dangerous for storage and transport of fuel, since it can cause fire hazards. On the other hand, high ignition temperature causes difficulty in igniting the fuel, but the fuel is safe during the storage, handling and transport. Hence, an ideal fuel should have moderate ignition temperature.
3. **Low moisture content:** The fuel should have low moisture content. High percentage of moisture increases the ignition temperature and also reduces calorific value.

Products of combustion should not be harmful: Fuel, on burning should not giving out harmful gases such as CO , H_2S , SO_2 , PH_3 etc. In other words the gaseous products of combustion should not pollute the atmosphere.

4. **Combustion control:** One can avoid large wastage of valuable fuel if its combustion rate can be properly regulated and burning can be stopped immediately as and when desired.
5. **Low cost:** A good fuel should be readily available in bulk at a cheap rate.

Calorific value:

Calorific value of fuel is defined as “Amount of heat librated when a quantity of fuel is completely burnt in presence of oxygen or air”

Units:

The calorific value is normally expressed in *Calories/gram* (CGS), **J/ kg** (SI) and J/m^3 (gaseous fuel)

Gross (higher) calorific value (HCV or GCV):

Gross or HCV is the “ total amount of heat produced, when unit mass/volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature” Usually all fuels contains some hydrogen and when the calorific value of hydrogen containing fuel is determined experimentally, the hydrogen is converted into steam.

If the products of combustion are condensed to the room temperature, the latent heat of condensation of steam also gets included in the measured heat. Therefore it is always higher than the net calorific value

Net (lower) calorific value (LCV or NCV):

LCV is “the net heat produced, when unit mass/volume of the fuel is burnt completely and the products are permitted to escape”. In actual practice combustion products are not cooled to temperature but simply let off into the atmosphere. Since this calorific value does not include the latent heat of steam, hence, net calorific value is always lower than gross calorific value.

Net calorific value = GCV – LATENT HEAT OF WATER

$$\text{NCV} = \text{GCV} - \left[\% \text{H}_2 \times 0.09 \times \text{latent heat} \right]$$

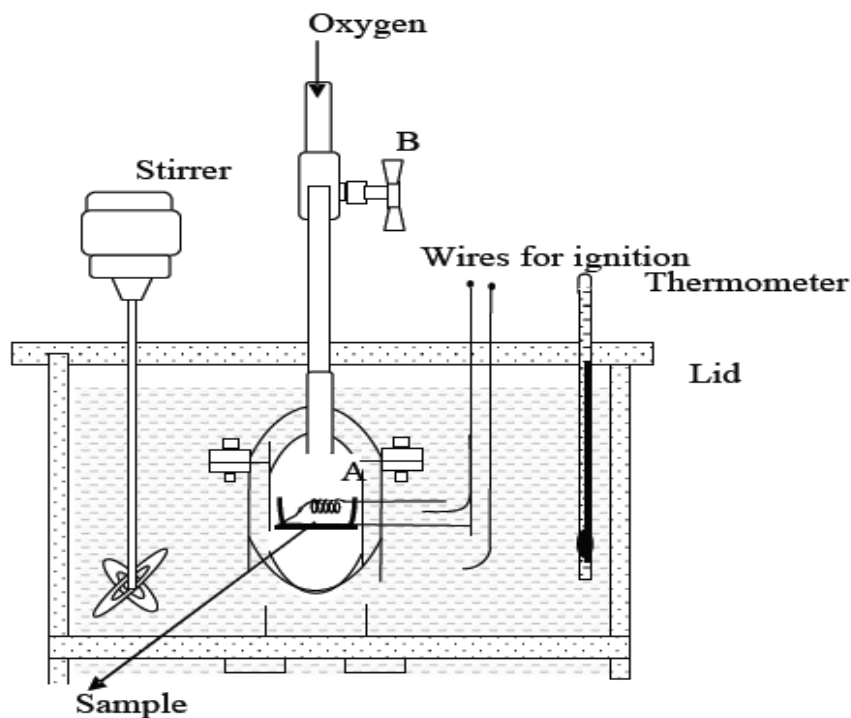
Because 1g of H_2 gives 9g of H_2O

Determination of calorific value of solid/liquid fuel using bomb calorimeter:

Calorific value of solid or liquid fuel is determined by using Bomb calorimeter.

Principle: A known weight of the sample (solid or liquid fuel) is burnt completely in excess of oxygen. Surrounding water and calorimeter absorbs the liberated heat. Thus the heat liberated during the combustion of fuel is equal to the heat absorbed by water and copper calorimeter. The higher calorific value of the fuel is calculated from the data.

Construction: It consists of a stainless steel airtight sealed cylindrical bomb. The bomb has an inlet valve for oxygen and is provided with two stainless steel electrodes. To one of the electrodes, a small ring attached. In this ring, a nickel or stainless steel crucible can be supported. The bomb is placed in a copper calorimeter, which is surrounded by an airtight and water jacket to prevent heat losses due to radiation. The calorimeter is provided with an electrically operated stirrer and thermometer.



Working: A known mass of the given fuel is taken in clean crucible. The crucible is then supported over the ring. Fine magnesium wire touching the fuel sample is then stretched across the electrodes. The bomb lid is tightly screwed and bomb filled with oxygen to 25 atmospheres. The bomb is then placed into copper calorimeter, containing a known mass of water. The stirrer is worked and initial temperature of the water is noted. The electrodes are then connected to 6 volt battery and circuit is completed. The sample burns and heat is liberated. Stirring of water is continued and the maximum temperature attained is recorded.

Calculation:

Weight of the fuel = m g

Weight of water taken in the calorimeter = w_1 g

Water equivalent of calorimeter = w_2 g

Initial temperature of water = t_1 °C

Final temperature of water = t_2 °C

Specific heat of water = 4.187 kJ/kg

Heat lost by m g of fuel = Heat gained by water + Heat gained by calorimeter

$$= (w_1 + w_2) (t_2 - t_1)$$

$$GCV = \frac{(W_1 + W_2)(t_2 - t_1) S}{m}$$

$$NCV = [GCV - \text{Latent heat of steam}]$$

Numerical problems:

1) Calculate calorific value coal samples from the following data.

Mass of the coal = 1g = 0.001kg

Water equivalent of calorimeter = 2 Kg.

Specific heat of water = 4.187 J/Kg/c.

Rise of temperature = 4.80C.

Solution:

$$GCV = \frac{(W)(\Delta t) S}{m}$$

$$GCV = \frac{(2)(4.8) 4.187}{0.001}$$

$$GCV = 40195.2 \text{ KJ/Kg.}$$

2) 0.6g of coal sample with 92% C, 5% hydrogen and 3% ash, caused a rise in temperature of 2000g water by 3.2⁰C in a bomb calorimeter experiment. Calculate the gross and net calorific value of coal, given water equivalent = 200g, specific heat of water = 4.187kJ/Kg/C, latent heat of steam = 580calories/ g (1cal = 4.187J)

Solution:

Mass of coal taken = 0.6g = 0.6 x 10⁻³kg

Hydrogen in coal sample = 5%

Rise in temperature of water = 3.20C

Mass of water taken = 2000g = 2000 x 10⁻³kg = 2.0 kg

Water equivalent of calorimeter = 200g = 200 x 10⁻³ kg = 0.2 kg

Specific heat of water = 4.187kJ/Kg/C

Latent heat of steam = 580calories/ g

$$= 587 \times 4.187 \text{ kJ/kg}$$

$$GCV = \frac{(W_1 + W_2)(t_2 - t_1) S}{m}$$

$$GCV = \frac{(2000 + 200)10 - 3(3.2) 4.187}{0.6 \times 10^{-3}}$$

$$GCV = 49127.46 \text{ kJ/kg}$$

$$NCV = GCV - 0.09 \times \%H_2 \times \text{latent heat of steam}$$

$$NCV = 49127.46 - 0.09 \times 5 \times (587 \times 4.187)$$

$$NCV = 48023.3 \text{ kJ/kg}$$

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- 3) The gross calorific value of bituminous coal is 36,000 kJ/kg. In an experiment 0.83 g of this coal is burnt under 1.2 kg of water in a bomb calorimeter. Due to combustion, the temperature of water rise by 3.92°C. calculate the water equivalent of calorimeter (specific heat of water = 4.2 kJ/ kg)

Solution:

Gross calorific value of bituminous coal sample = 36,000 kJ/kg

Mass of coal taken = 0.83g = 0.83×10^{-3} kg

Mass of water = 1.2 kg

Rise in temperature = 3.92°C

specific heat of water = 4.2 kJ/ kg

$$GCV = \frac{(W_1 + W_2)(t_2 - t_1) S}{m}$$

$$36000 = \frac{(1.2 + W_2)(3.92) 4.187}{0.83 \times 10^{-3}}$$

$$36000 = [1.2 + 22.483] + [W_2 \times 22.483]$$

$$= 26980 + [W_2 \times 22.483]$$

$$W_2 = \frac{36000 - 26980}{22.483}$$

$$W_2 = 0.409 \text{ kg}$$

- 4) On burning 0.75×10^{-3} kg of a solid fuel in a bomb calorimeter, the temperature of 2.5 kg water increased from 24°C to 28°C . The water equivalent of calorimeter and the latent heat of steam are 0.485 kg and $4.2 \times 587 \text{ kJ/kg}$ respectively. Specific heat of water is $4.2 \text{ kJ/kg}^\circ\text{C}$, if the fuel contains 2.5% hydrogen; calculate its gross and net calorific values.

Solution:

Mass of fuel = $0.75 \times 10^{-3} \text{ kg}$

Water equivalent of calorimeter = 0.485 kg

Latent heat of steam = $4.2 \times 587 \text{ kJ/kg}$

Increase in temperature = 4°C

$$GCV = \frac{(W_1 + W_2)(t_2 - t_1) S}{m}$$

$$GCV = \frac{(2.5 + 0.485)(4) 4.187}{0.75 \times 10^{-3}}$$

$$GCV = 66657.04 \text{ kJ/kg}$$

$$NCV = GCV - 0.09 \times \%H_2 \times \text{latent heat of steam}$$

$$NCV = 66657.04 - 0.09 \times 2.5 \times (587 \times 4.2)$$

$$NCV = 66104.00 \text{ kJ/kg}$$

Knocking of petrol engine:

In petrol engines, the mixture of petrol and air is drawn in to the cylinder. The fuel-air mixture is compressed by the piston and is ignited by an electric spark.

The power output and efficiency of an IC engine depends on the compression ratio which is the ratio of the volume of the cylinder at the end of the suction stroke to the volume of the cylinder at the end of the compression stroke.

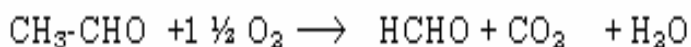
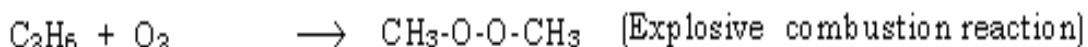
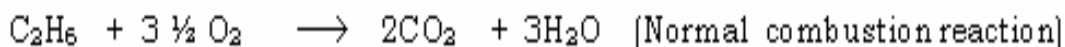
$$\text{compression ratio} = \frac{\text{volume of cylinder at the end of suction stroke}}{\text{volume of cylinder at the end of compression stroke}}$$

As the flame front travels in the combustion chamber, rapidly expanding combustion products compress the remaining unburnt fuel and raise its temperature. If the flame front travels rapidly at an optimum speed, the combustion of unburnt fuel takes place smoothly. On the other hand, if the flame front travels too slowly, the entire last portion of the fuel mixture may get heated up beyond its ignition temperature and undergoes instantaneous explosive combustion. This results in emission of characteristic rattling sound called “knocking”.

Definition: knocking may be defined as the production of a shock wave in an IC engine as a result of an explosive combustion of fuel air mixture, leading to a rattling sound.

Mechanism:

- Under ideal condition there is a slow oxidation of fuel, during which oxygen combines with a few hydrocarbons and activates them
- The activated molecules combine with hydrocarbon molecules and chain reaction is set up resulting in a smooth combustion
- Sometimes, due to deposition of carbon on the walls of the cylinder the hydrocarbons in petrol molecules are activated and they combine at a faster rate to set up a chain reaction forming peroxy compounds
- The accumulated peroxide decomposes suddenly and bursts into flames producing shock waves
- The shock waves hit the walls of engine and piston with a rattling sound, this is known as knocking
- The reactions that take place in IC engine are given below



Ill effects:

1. It produces undesirable rattling noise.
2. It increases the fuel consumption.
3. It results in decreased power output.
4. Mechanical damage of piston and engine walls of IC engine.
5. The driving and travelling becomes unpleasant.

Prevention:

1. A suitable change in engine design.
2. By using high rating gasoline.
3. By using critical compression ratio.
4. By using anti-knocking agents.

Antiknocking agent:

Antiknocking agents are chemical substance having a capacity to prevent or control knocking of petrol is called as antiknocking agent.

Example:

1. Tetraethyl lead
2. Tetramethyl lead and a mixture of TEL AND TML is used as anti-knocking agents.
They are used along with ethylene dichloride or ethylene dibromide.

Unleaded petrol:

Unleaded petrol is the petrol it does not containing lead compound as antiknocking agent. In addition to it, compounds like Methyl tertiary butyl ether (MTBE) is added to improve octane

number of unleaded petrol in IC engines, thereby reducing considerably the formation of peroxy compounds (which causes knocking)

Advantages of unleaded petrol:

1. Eliminates the pollution level of lead in atmosphere.
2. This permits the attachment of catalytic converters to the exhaust pipe in automobiles.

The catalyst converts the toxic exhaust gases like CO and NO to non-toxic gases CO₂ and N₂ respectively. Consequently, the pollution level is reduced to a great extent.

NOTE: Leaded petrol cannot be used in automobile exhaust pipes fitted with catalytic converter, since the released lead compounds poisons the catalyst itself, thereby destroying its catalytic activity.

Power alcohol: "A mixture of ethyl alcohol and gasoline blend which can be used as fuel in internal combustion engine is known as power alcohol"

Absolute alcohol is mixed with ether, benzene etc. compounds and volume of this is mixed with four volumes of petrol and is used as a fuel.

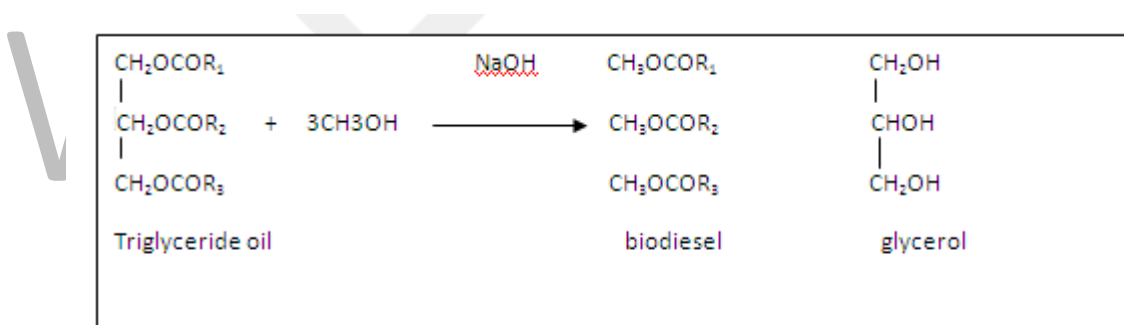
Advantages:

- The power output is good
- It has better antiknocking property
- Ethanol is biodegradable, hence it is eco friendly fuel
- It reduces carbon monoxide emission

Biodiesel:

- Biodiesel is a renewable, oxygenated fuel obtained from variety of agricultural resources such as soya seeds and rape seeds.
 - Biodiesel is nontoxic, biodegradable, replacement for petroleum diesel. Chemically biodiesel is a fatty acid monoalkyl ester.
 - The oil/fat are triglycerides esters of fatty acids and their use in engine require extensive engine modification
-

- However it is possible to convert these triglycerides into substance of diesel quality by transesterification
- “ Transesterification is alcoholysis of the triglyceride oil in the presence of a base like NaOH to obtain biodiesel. Thus biodiesel is a mixture of monoalkyl esters of long chain fatty acids”
- The transesterification of triglycerides esters with methanol in presence of NaOH is given as
- The direct transesterification in presence of alkali results in the formation of soap. This soap forms a semi solid mass at ambient temperature and affects the separation of glycerol from diesel layer
- This soap formation is avoided by first esterifying in presence of acid catalyst. This is followed by base catalysed transesterification to get biodiesel.



Advantages:

- It is made by using renewable sources and feed stock
- Readily undergo biodegradation, nontoxic
- This has higher flash point than the diesel but lower ignition point
- It has higher cetane number(48-60) compared to petroleum diesel(40-55)
- Use of biodiesel reduces green house gases

Fuel cell:

Definition: Fuel cells are electrochemical devices that convert the chemical energy of a fuel directly and very efficiently into electricity (DC) and heat, thus doing away with combustion.

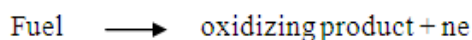
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A fuel cell has two electrodes and an electrolyte. In the fuel cell device, fuel and oxidants are continuously and separately fed into their respective electrodes, at which they undergo redox reactions generating electrical energy. A notable feature is that fuel cell produce electrical energy with continuous replenishment of the fuel at the electrode.

A fuel cell may be represented as: **Fuel / electrode // electrolyte // electrode / oxidant**

Reactions:

At anode: fuel undergoes oxidation



At cathode: the oxidant gets reduced



Difference between conventional cell and fuel cell:

| Conventional cell | Fuel cell |
|---|---|
| (1) The electrons are not assisted with catalyst | The electrodes are impregnated with catalyst |
| (2) It stores chemical energy | It do not store chemical energy |
| (3) The electrodes in some cases are consumed during the production of energy | The electrodes are not consumed during the production of energy |
| (4) The active materials are complex chemical compositions (electrode) | The active materials are fuels and oxidants |
| (5) Create chemical pollution in the atmosphere | Less harmful, biproducts are discharge to atmosphere |
| (6) Recharging of the cell is required | Recharging of the cell is not required |

Advantages of Fuel Cells

- Their power efficiency is high

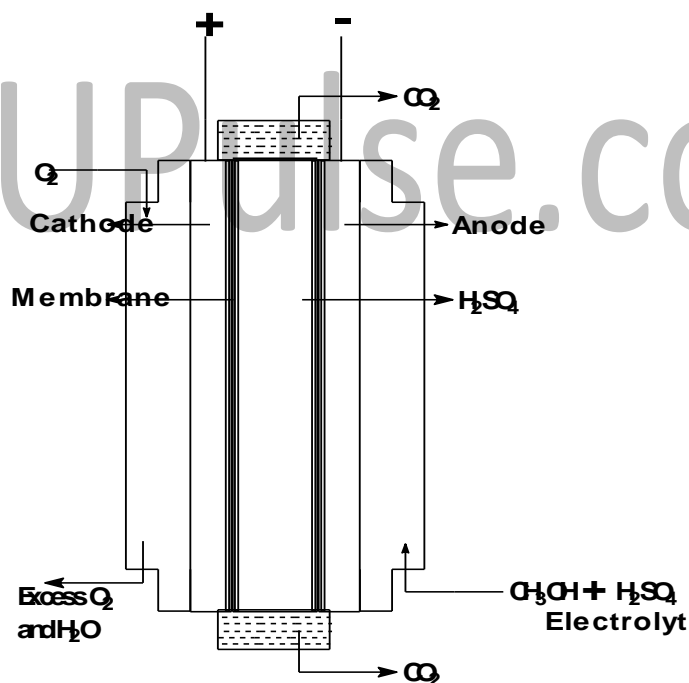
- They are eco-friendly since the products of the overall reactions are not toxic and hence pose no pollution problems
- They can produce direct currents for long periods at a low cost

Methanol-Oxygen Fuel Cells:

Methanol is one of the most electro active organic fuels in the low temperature range.

It is mainly because:

1. It has low carbon content
2. It possesses a readily oxidisable OH group
3. It has high solubility in aqueous electrolyte

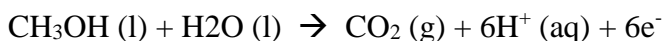


- The cell produces an emf of 1.20 V at 25⁰ C
- Methanol containing some sulphuric acid (3.7 M) and circulated through anode chamber.
- Pure oxygen is passed through the cathode chamber and sulphuric acid, is placed in the central compartment.
- Both electrodes are made of platinum
- A membrane is inserted adjacent to the cathode on the inner side to minimise diffusion of methanol into the cathode.

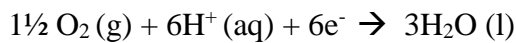
- In absence of the membrane, methanol diffuses through the electrolyte into the cathode and undergoes oxidation.
- An advantage of the use of an acid electrolyte is that the CO₂, a product of the reaction can remove easily.

Reactions:

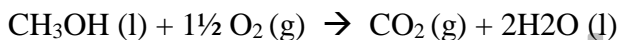
At anode:



At cathode:



Overall reaction:

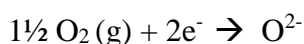


Applications:

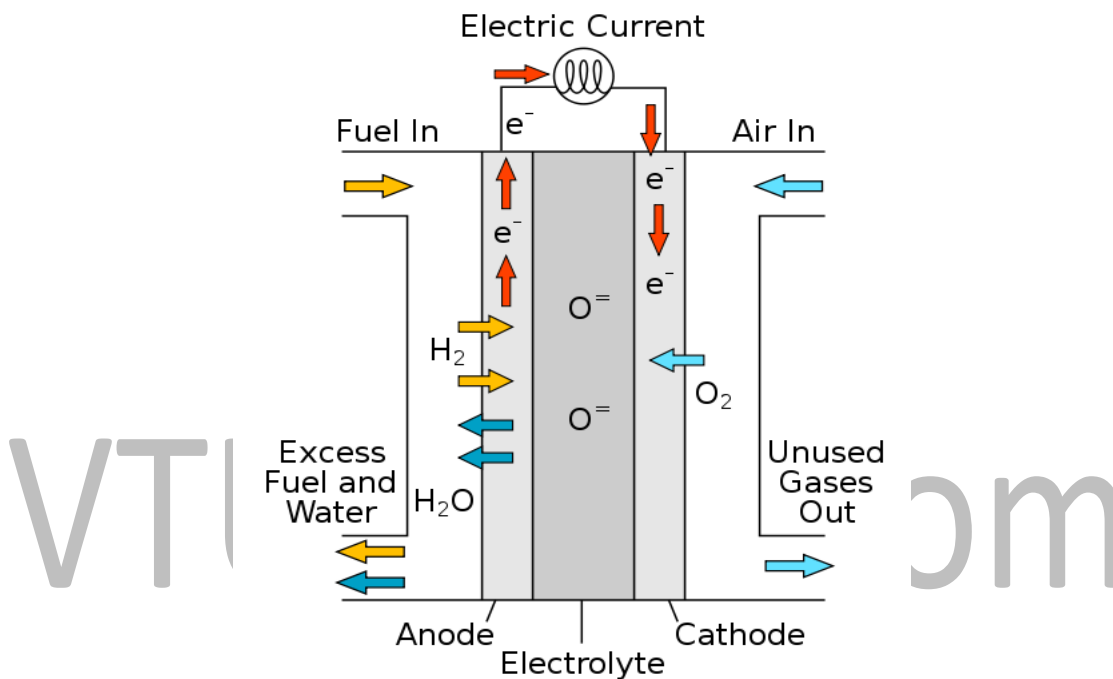
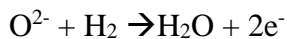
Used in military applications and in large scale power production.

Solid oxide fuel cell (SOFCs):

- They use a solid ceramic electrolyte, such as zirconium oxide stabilised with yttrium oxide, instead of a liquid.
- They operate at 800 to 1,000°C.
- In solid oxide fuel cells, negative ions travel through the electrolyte to the anode where they combine with hydrogen to generate water and electrons.
- The anode is typically constructed from electrically conducting Ni/yttria stabilized zirconia cermet (Ni/YSZ).
- The cathode is based on a mixed conducting lanthanum manganate (La MnO₃)
- Cathode: Oxygen supplied at the cathode reacts with the incoming electrons from the external circuit to form oxygen ions, which migrate to the anode through the oxygen ion conducting electrolyte.



- Anode: oxygen ions combine with hydrogen in the fuel to form water liberating electrons. Electrons flow from the anode through the external circuit to the cathode.



Application:

- SOFC are being targeted for use in power and heat generation for homes and business as well as auxiliary power units for electrical systems in vehicles
- SOFC also can be linked with a gas turbine, in which the hot, high pressure exhaust of the fuel cell can be used to spin the turbine, generating a second source of electricity
- Using planar SOFCs in stationary power generation systems of 1 kW to 25 kW size have been fabricated and tested by several organization

Solar energy:

The radiations reaching earth from the sun and converting them into different useful forms of energy is called solar energy.

The utilization of solar energy is of two types—Direct solar power and indirect solar power.

Advantages:

- The Solar power is pollution free.
- It can operated with little maintenance or intervention after initial setup.
- The Solar power is becoming more and more economical as costs associated with production decreases, and the technology becomes more effective in energy conversion.
- The Solar power can be viewed as a local resource because of original climatic variances.

Disadvantages:

- The Solar power is only practical in certain areas with a favorable climate and latitude. That is, are as near the tropics and which is cloud free is relatively.
- The Solar power is not available at night.
- The Solar power decreases during cloudy.
- The Solar power must be converted in to some other form of energy to be stored.
- Solar cell technologies produce DC power which must be converted to the AC power.

Photovoltaic cell

Photovoltaic cells or Solar cells are the semiconductor devices which converts sunlight into direct current electricity on illumination.

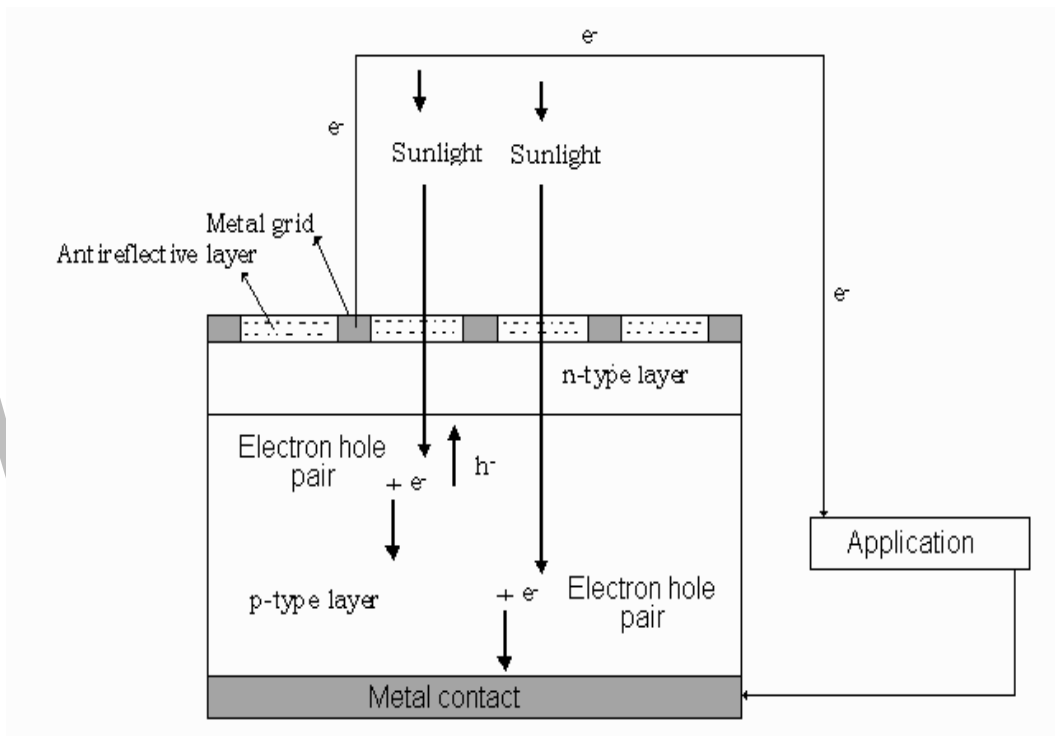
Construction and working of photovoltaic cells:

The Solar cells or Photovoltaic cells are made out of semiconductors which have the capacity to absorb light. When n-type and p-type semiconductor are brought together a semiconductor diode is formed. The semiconductor diodes collect the carrier's and conducts the generated electrical current preferentially in a specific direction.

A typical silicon photovoltaic cell is composed of a thin wafer consisting of an ultra thin layer of phosphorus doped.(n-type)silicon onto p of boron doped (p-type) silicon. Hence a p-n junction is formed. A metallic grid forms one of the electrical current contact so the diode and allows light to fall on the semiconductor between the gridlines. An anti reflective layer between the gridlines increases the amount of light transmitted to the semiconductor. The cell's other electrical contacts is formed by a metallic layer on the back of the solar cell.

Working:

When light radiation falls on the p-n junction diode, electron-hole pairs are generated by the absorption of the radiation. The electrons are drifted to and collected at the n-type end and the holes are drifted to p-type end. When the two ends are electrically connected through a conductor, there is a flow of current between the two end sthrough the external circuit.thus photoelectric current is produced.



Importance of Photovoltaic cell:

- The conventional energy is exhaustible and depleting. Whereas Solar energy is ultimate, inexhaustible, and renewable energy. Therefore, photovoltaic cells are an important means to utilize this continuous energy source.
- Photovoltaic cells can serve for both off-grid and on-grid applications. They can be used for off-grid professional devices and supply systems such as telecommunication equipment, solar home systems, etc.
- Photovoltaic energy conversion is environmentally friendly as there is no harmful emission of pollutants.
- The use or production of solar energy doesn't produce noise pollution.

- The electricity obtained from solar energy is useful in minimizing global warming due to carbon dioxide.
- Photovoltaics can be used as roof integrated systems, providing power and also serving as optical shading elements for the space below and preventing over heating in the summer.
- Photovoltaic cells provide power for space craft and satellites.
- Developments in the field of photovoltaic cells will boost the semiconductor industry and storage battery industries

Preparation of solar grade silicon by union carbide process:

Production of semiconductor grade silicon involves the following three stages.

i) Production of metallurgical grade silicon (Carbothermic reduction of silica)

Metallurgical grade silicon of purity of 98.5% Si is produced in submerged electrical arc furnace. The furnace consists of a crucible filled with quartz and carbon (metallurgical coke or coal). Silicon is formed as follows.



Silicon is formed as molten state and is tapped from the bottom of the furnace. The carbon monoxide further oxidized to carbon dioxide and released into the atmosphere.

ii) Refining of silicon:

The crude silicon obtained in the above method is taken in a large ladle and treated SiO_2 and lime/limestone (CaO/CaCO_3). The less elemental than silica such as Al, Ca and Mg are oxidized as their oxides.

