خلايا الوقود :Fuel cells

A **fuel cell** is an <u>electrochemical cell</u> that converts the <u>chemical energy</u> that is generated from a fuel into electricity through an <u>electrochemical</u> reaction of <u>hydrogen fuel</u> with oxygen or another <u>oxidizing agent</u>. <u>Fuel</u> <u>cells are different from batteries in requiring a continuous source of</u> <u>a fuel and oxygen (usually from air) to sustain the chemical reaction</u>, whereas in a battery the chemical energy comes from chemicals that are already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the <u>anode</u>, the <u>electrolyte</u>, and the <u>cathode</u>. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, <u>water or carbon dioxide is created</u>, and an electric <u>current is created</u>, which can be used to power electrical devices, normally referred to as the load.

At the anode pot, a <u>catalyst</u> oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion(H^+) and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, <u>usually oxygen</u>, to create water or carbon dioxide.







Figure: General Scheme of fuel cell

<u>Pusting of Iron by water droplet: صدأ الحديد</u>

The amount of water complexed with the iron (III) oxide (ferric oxide) varies as indicated by the letter "X". The amount of water present also determines the color of rust, which may vary from black to yellow to orange brown. The formation of rust is a very complex process which is thought to begin with the oxidation of iron firstly to ferrous (Fe²⁺) ions.

 $Fe \rightarrow Fe^{2+} + 2 e^{-}$

Both water and oxygen are required for the next sequence of reactions. The iron (+2) ions are further oxidized to form ferric ions (iron "+3") ions.

 $Fe^{2+} \rightarrow Fe^{3+} + 1 e^{-1}$

The electrons provided from both oxidation steps are used to reduce oxygen as shown:

 $O_{2(g)} + 2 H_2O + 4e^- \rightarrow 4 OH^-$

The ferric ions then combine with oxygen to form ferric oxide [iron (III) oxide] which is then hydrated with varying amounts of water. The overall equation for the rust formation may be written as:

 $4 \operatorname{Fe}_{(s)} + 6 \operatorname{H2O}_{(l)} + 3 \operatorname{O}_{2(g)} \rightarrow 4 \operatorname{Fe}(OH)_{3(s)},$

Then $Fe(OH)_3$ dehydrates to produce $Fe_2O_3.nH_2O_{(s)}$. Thereby, the chemical formula for rust is $Fe_2O_3.nH_2O$. Other metals, other elements such as aluminium don't rust significantly, these metals form an oxide layer when they come into contact with oxygen from the air but this layer of oxide bonds very strongly

to the surface of the aluminium preventing further oxidation to continue.

However, in some cases, Aluminum can rust in a very short time if a thin layer of mercury(Hg) is applied to the surface. Mercury readily combines with aluminum to form a mercuryaluminum amalgam when the two pure metals come into contact. When the amalgam is exposed to air, the aluminum oxidizes, leaving behind mercury. The oxide flakes away, exposing more mercury amalgam, which repeats the process thus a small amount of mercury can rust a large amount of aluminum over time, for this reason, mercury is prohibited on aircraft.

التاكل :Corrosion

Corrosion is an <u>electrochemical oxidation</u> of metal in reaction with an oxidants such as <u>oxygen</u> or <u>sulfates</u>. **Corrosion** is a <u>natural process</u>, which converts a refined metal to a more chemically-stable form, such as its <u>oxide</u>, <u>hydroxide</u>, or <u>sulfide</u>. It is the gradual destruction of materials (usually <u>metals</u>) by chemical and/or electrochemical reaction with their environment. <u>Corrosion science</u> is the field dedicated to controlling and stopping corrosion. In the most common use of the word, this means <u>electrochemical oxidation</u> of metal in reaction with <u>oxidants</u> such as <u>oxygen</u> or <u>sulfates</u>.

<u>Rusting</u>, formation of <u>iron</u> oxides, is a well-known example of electrochemical corrosion. This type of damage typically produces <u>oxide(s)</u> or <u>salt(s)</u> of the original metal, and results in a distinctive orange coloration. Corrosion can also occur in materials other than metals, such as <u>ceramics</u> or <u>polymers</u>, although in this context, the term "degradation" is more common. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

Many structural <u>alloys</u> corrode merely from exposure to moisture in air, but the process can be strongly affected by exposure to certain substances. Corrosion can be concentrated locally to form a <u>pit</u> or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion-controlled process, it occurs on exposed surfaces of metals and other materials.

أنواع التاكل:Types of Corrosion

There are different types of corrosion which depends on: 1-Environment surrounding the material, (air, H_2O , sulfide, acids,

2-Type of material,

3-Chemical reaction.

Some general types of corrosion are described below:

1. Uniform Corrosion: التاكل المنتظم

This is also called **General corrosion**. It is a very common method of corrosion. It occurs at the whole surface of the metal and makes the surface with timea thin. The damage is done at a constant rate on the entire surface. It can be easily detected by it's appearance. It can be controlled but if it is not, it then destroys the whole metal surface.

<u>التاكل الكلفائى او الكهربائى:(electrical corrosion) التاكل الكلفائى او الكهربائى:</u>

This type of corrosion occurs in the presence of (electrolyte) like seawater. Metals have different values of electrical potentials.

When they become electrically connected to each other and put in an electrolyte, the more active metal which has a high negative potential becomes the anode. Due to its high negative potential, it corrodes fast. But the less active metal becomes the cathode and grow up and becomes thicker.

The flow of electric current continues till the potentials are equal between both electrodes. <u>So at the joint where the two non</u> <u>similar metals meet, the galvanic corrosion appears</u>. The Galvanic Series shows the list of metals from the most active to the least active (most noble). Thus galvanic corrosion can be controlled by selecting the two metals which are close in series as platinum is the least active, it is also less active for corrosion.

<u>3. Pitting Corrosion</u> التاكل المثقابى:

This occurs because of random attacks on particular parts of the metal's surface. This makes (holes) which are large in depth. These holes are called "pits". This pit acts as the anode while the undamaged part of the metal is the cathode. It begins with a chemical breakdown in the form of a scratch or spot. The pitting process makes the metal surface uniform and increases fatigue.

Corrosion Theories and mechanism:

1. Water on the metal surface dissolves CO_2 and O_2 from the air.

$$H_{2} O + CO_{2} \longrightarrow H_{2} CO_{3}$$

$$H_{2}CO_{3} \textcircled{}{} 2H^{+} + CO_{3}^{2^{-}}$$

$$H_{2}O \xleftarrow{} H^{+} + OH^{-}$$

2. Fe in contact with dissolved CO₂ and O₂ undergoes oxidation.

$$Fe = Fe^{2+} + 2e^{-}$$
 Anode

3. Electrons lost by Fe are taken by H⁺

$$H^+ + e^- = 1/2H(g)$$

 $4H_{(g)} + O_{2(g)} = 2H_2O_{(g)}$

4-On multiplying the first equation by 4 and adding to the second,

 $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

The dissolved O₂ can take electrons directly also.

 $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ Cathode

$$Overall \ 2Fe_{(s)} + O_{2(g)} + 4H^{*}_{(aq)} \longrightarrow 2Fe^{2+}_{(aq)} + 2H_{2}O$$

5. Fe^{2+} reacts with dissolved O_2 and water:

$$4Fe^{2+} + O_2 + 4H_2O \longrightarrow 2Fe_2O_3 + 8H^+$$

$$Fe_2O_3 + \times H_2O \longrightarrow Fe_2O_3 \cdot \times H_2O$$

Rust is a hydrated ferric oxide(Fe₂O₃.XH₂O).

الوقاية من التاكل: Corrosion Protection

Given below are some of the factors that cause corrosion.

- Reactivity of metal
- Presence of impurities
- Presence of air, moisture, gases like SO₂,H₂S, O₂ and CO₂
- Presence of electrolytes

Currently, two methods are used for the protection of materials from corrosion:

- 1. Cathodic protection [electrical] protection
- 2. Corrosion inhibitors.

<u>1-Cathodic protection or electrical protection</u>

The principle of this method is to alter the electrode potential of the metallic structure so that they can lie in the <u>immunity</u> <u>region</u>. This is the region where the metal is in the stable state of the element and corrosion reactions are not possible. It is mostly used in <u>steel structures in marine and under ground</u> <u>regions</u>. Two methods are used to apply the cathodic protection to a metal structure these are:

a-Impressed Current: التيار المسلط

This method is used for the protection of pipelines and the hulls of ships in sea water. In this method, an electric current is applied to the metal surface by use of DC electrical circuit. The negative and positive terminal of the current source is connected to the metal requiring protection and an auxiliary anode respectively. The flow of electric current charges the structure with electrons and changes the electrode potential in the negative direction. This process continues till it reaches the **immunity region**. The current flows from anode to cathode, thus it protects the metal surface from corrosion.

الانود المضحى :b-Sacrificial Anode

This is especially used for ships, marine oil structure and gas production platform etc. In this technique, the more reactive metal is used to alter the electrode potential and get the <u>immunity region</u>. Zinc is generally used as sacrificial anode. It generates the anodic dissolution current with more negative potential. The cathodic curve intersection is now at a more negative potential which is the immunity region. At this region, the corrosion rate of steel is negligible.

2. Corrosion Inhibitors

According to surface chemistry, the presence of foreign molecules affects the surface reactions. Corrosion processes are also a type of surface reactions. These can be controlled by foreign compounds which are known as inhibitors.

The inhibitors get adsorbed on the reacting metal surface. It attaches directly to the surface or adsorbs up to one molecular layer of the metal surface. This is a well known method for controlling the corrosion. The inhibitors can work in different ways; it may block the active sites of corrosion and restrict the rate of anodic or cathodic process, or it may increase the electrode potential etc.

Important example of corrosion inhibitors are hexylamine or sodium benzoate, these are used as inhibitors for anodic reactions.

Similarly, oxidizing agents like nitrite, chromate, red lead, amines, thio-urea etc are also used as corrosion inhibitors. Different types of paints are also used widely as inhibitors for corrosion reactions.