## The corrosion of metals engineering essay



Each year, billions of dollars are spent on repairing and preventing the damage of metal parts caused by corrosion, the electrochemical deterioration of metals. The majority of metallic materials in a practical context are generally exposed to corrosion in both atmospheric and aqueous environments. Metallic corrosion has become a global problem which has negatively affected the industrialised society; hence why it has been studied in such comprehension since the beginning of the industrial revolution in the late eighteenth century. ' Corrosion also affects the average daily life both directly, as it affects the commonly used service possessions and indirectly, as producers and suppliers of goods and services incur corrosion costs, which they pass on to consumers.' (ASM International, 2012). The effects of corrosion are distinctively recognized on automobile parts, charcoal grills and metal tools all of which will have a depleted efficiency once corroded. This corrosion may result in contamination which then poses health risks. For example, the pollution due to escaping product from corroded equipment or due to a corrosion product itself. As a result of these consequences, corrosion prevention has been studied in great depth. Corrosion of various metals may be prevented by applying a coating of paint, lacguer, grease of a less active metal to keep out air and moisture. These coatings will continue to suppress the effects of coating so long as they stay intact. Examples of metals that are heavily protected in the industrial world are iron and aluminium. Vast guantities of the ores or each metal are mined and processed each year using large scale chemical reactions to produce metals

of the purity required for their end use. For this report, the chemistry involved in the corrosion of both iron and aluminium will be researched as well as the methods employed to prevent their corrosion. Justification as to why corrosion happens will be explained with reference to physical and chemical properties, electrochemistry, equilibrium, rates of reaction, enthalpy and solubility at every point where it is appropriate.

Before explaining why corrosion happens, it is important to define corrosion in terms of electrochemical processes. An electrochemical reaction is defined as a chemical reaction involving the transfer of electrons through redox. Corrosion is a broad and complex subject that can be examined in three different categories; electrochemical corrosion, galvanic corrosion and electrolytic corrosion. In all forms of corrosion, three components must be present – an anode, a cathode, a metallic path for electrons to flow through, and an electrolyte for the ions to flow through. Both the anode and the cathode must be in contact with the electrolyte to allow the ions to flow. As well as this, oxygen and hydrogen must also be available, either directly or as a result of chemical action and the resultant dissociation of water into its two constituents.

In this report, electrochemical will be investigated in terms of its spontaneous nature and self-sustainability. Firstly, spontaneity is dependent on the sign of free energy. Gibb's free energy can be defined by the following equation:; where is the enthalpy, is entropy and is the temperature in kelvins. When is negative, the reaction will occur spontaneously (Zhang, H. 2012). For this to occur the entropy must increase and the enthalpy must decrease. This can be proven as a system of spontaneity aims towards disorder which directly coincides with entropy. Also, the change in enthalpy must be negative as thermal energy will be released from the energy stored within chemical bonds in a spontaneous system.

Furthermore, in this electrochemical procedure, the negative electrode is the cathode and the positive electrode is the anode. Note that metals are used as they are good conductors of electric current due to the specific ionic bonding which then allows the electrons to be delocalized and move relatively freely. When these two electrodes are connected by a wire, free electrons flow through the wire from the anode to the cathode forming an electric current. Both the anode and cathode are submerged in separate substances respective to the elements of both electrodes from which the positive ions are attracted to the anode and the negative electrons are attracted to the cathode. The anode atoms are being oxidised as they are losing electrons and forming positive ions which then dissolves into solution. This results in a loss of overall quantity of zinc metal. In practical terms, this could be considered the 'pitting' of the corrosion process which can be defined as ' a form of extremely localized corrosion that leads to the creation of small holes in the metal' (ASM International, 1987). Electrons formed at the anode travel to the cathode where they combine with the positive ions in solution to turn into the respective metal. Therefore the cathodic ions in solution are being reduced as they are gaining electrons. This production of extra cathode metal can be compared with rust which is ' a reddish- or yellowish-brown flaky coating of iron oxide that is formed on a metal by redox reactions.'

With just this in mind, the electric current would flow for only a limited time as the anode would have a build-up of positive ions being formed. While at the cathode increased amounts of electrons are being pumped into it. ' The result is an excessive positive charge that builds up at the anode that

attracts electrons (negative) and prevents them moving away. While at the cathode the negative build up repels the electrons. As a consequence of this build-up of charge, no electron flow occurs and the cell eventually fails' (Dynamic Science, 2012). Note that a solution cannot have a full charge and only a partial charge. To negate this issue, a salt bridge is used which contains ions that complete the circuit by moving freely from the bridge to the half cells. The substance that is placed into the salt bridge is usually ' an inert electrolyte whose ions are neither involved in any electrochemical change nor do they react chemically with the electrolytes in the two halfcells' (IIT, 2012). As well as completing the circuit, it ensures that the charge between the two half cells remains electrically neutral. It does this by passing negative ions into the anodic half-cell where there shall be an accumulation of extra positive ions due to oxidation resulting in a slightly positive charge. Similarly, an accumulation of negative ions will exist in the cathodic half-cell due to the deposition of positive ions by reduction. Electrical neutralization is once again achieved by the salt bridge providing positive ions to the cathodic substance. Thus, the salt bridge maintains electrical neutrality.

## **IRON CORROSION**

Only a few metals, such as copper, gold and platinum occur naturally in their elemental forms. Most metals occur in nature as oxides in ores, combined with some unusable metal like clay or silica. Ores must be processed to get the pure metals out of them, and there are nearly as many different processes for this purpose as there are metals. The process, as well as the elements present, greatly influences the properties of the metal. An https://assignbuster.com/the-corrosion-of-metals-engineering-essay/

important characteristic of metals is the extremely significant effect that very small amounts of other elements can have upon their properties. The huge difference in properties resulting from a small amount of carbon allowed with iron to make steel is an example of this. Taking into consideration the amount of iron that is used globally, the effect of corrosion on iron alone requires millions of dollars each year. ' The problem with iron as well as many other metals is that the oxide formed by oxidation does not firmly adhere to the surface of the metal and flakes off easily causing " pitting" (KKC, 2012). Extensive pitting eventually causes structural weakness and disintegration of the metal. The iron oxide acts as a sacrificial anode which is a stronger reducing agent than iron that is oxides instead of the protected metal. Therefore it can be said that it acts as the anode. Since the oxide does not firmly adhere, it does little to protect the iron metal. As mentioned, iron in contact with moisture and air (oxygen) is corroded by a redox reaction. The anode reaction can be expressed as an oxidation of iron atoms:

Both water and oxygen are required for the next sequence of reactions. The iron ions are further oxidized to form ferric ions (iron ") ions. This can be written as:

These electrons are then conducted through the metal and are used to reduce atmospheric oxygen to hydroxide at another region of the iron. Therefore the cathodic reaction is:

Considering that iron atoms dissolve at the anodic sides to form pits and ions which diffuse toward the cathodic sites; ions are formed at cathodic sites diffuse toward the anodic sites. Iron (II) hydroxide forms in a random location between the cathode and the anode which is then oxidised by atmospheric oxygen to iron (III) hydroxide. This can be expressed by:

From here, the iron (III) hydroxide is then gradually converted to rust otherwise known as hydrated iron (III) oxide:

; Where generally equals 3.

The formation of rust does not have a designated position as it can occur at random away from the actual pitting or corrosion of iron. ' A possible explanation of this is that the electrons produced in the initial oxidation of iron be electrically conducted through the metal and the iron ions can diffuse through the water layer to another position on the metal surface which is available to the atmospheric oxygen' (KKC, 2012). Also, points of stress, such as where the piece of metal has been shaped, are more active than unstressed regions and thus act as anodic sites. The electric current between the anodic and cathodic sites is completed by ion migration; thus, the presence of electrolytes increases the rate of corrosion by hastening this mitigation. Therefore it is evident that the corrosion of iron can be directly related to a voltaic cell and can both be defined as electrochemical cells due to their spontaneous nature.

## **ALUMINIUM CORROSION**

Similar to Iron, aluminium is also susceptible to electrochemical corrosion when exposed to moister. Aluminium, both in its pure state and allow, is truly a remarkable metal as it is light, tough, strong and readily worked by all common processes. Unlike iron however, It has excellent resistant to https://assignbuster.com/the-corrosion-of-metals-engineering-essay/ corrosion in the marine environment, and it requires little maintenance. ' The fundamental reactions of the corrosion of aluminium in aqueous medium have been the subject of many studies. In simplified terms, the oxidation of aluminium in water proceeds according to the equation' (ELSIVIER, 2012):

This specific reaction is balanced by a simultaneous reduction reaction, similar to iron, in ions available in the solution which then consumes the oxidised electrons. In an aqueous solution such as fresh water, seawater or moisture, thermodynamic considerations can be used to represent only two possible reduction reactions that can occur. The other occurring reaction is the reduction of oxygen dissolved in the moisture:

Quite similar to the corrosion of iron, the aluminium atoms dissolve at the anodic sites to once again form pits and which diffuse toward the cathodic sites while ions are formed at the cathodic sites and diffuse toward the anodic sites. Therefore:

; Where generally equals 3.

Although aluminium is still susceptible to corrosion, the metal itself is very resistive. Aluminium alloys generally have excellent resistance to atmospheric corrosion; require no protective coatings or maintenance beyond cleaning, which aids greatly in preventing unsightly pitting where dirt or salt accumulate. When aluminium is exposed to oxygen, it forms an oxide surface film that protects it from corrosive attack. The oxide acts as a sacrificial anode which is a stronger reducing agent than aluminium. It is then oxidised instead of the protected aluminium metal, serving as the anode. For the most part, damage due to atmospheric corrosion is pretty https://assignbuster.com/the-corrosion-of-metals-engineering-essay/ much limited to fairly slightly pitting of the surface with no significant loss of material or strength. Duration of exposure is an important consideration in aluminium allows, the rate of corrosion decreases with time to a low steady rate regardless of the type of allow or the specific environment. Thus corrosion of both aluminium and iron can both be defined as electrochemical processes which are similar in nature but have different protection potentials.

## PROTECTION METHODS

Corrosion avoidance begins in the design process. Although corrosion concerns may ultimately reduce structural integrity, they should be a consideration to decrease money loss. Good maintenance practices are another way of avoiding corrosion, such as rinsing away salt water or avoid standing water. Corrosion protection systems, for the most part, are designed to control corrosion, not necessarily eliminate it. The primary goal is to reduce the rate of corrosion by having the smallest possible current. Current is defined as the flow of charge, or electrons, per time through a conductor hence. Since corrosion is the movement of electrons through redox, it can be quantified using this equation which represents the corrosion reaction per time or the corrosion rate. To do this, two efficient protection methods are available: cathodic protection systems and coatings.

All cathodic protection schemes operate on the basis of the voltaic corrosion process, so like voltaic corrosion; cathodic protection systems require an anode, a cathode, an electrical connection and an electrolyte. Cathodic protection will not reduce the corrosion rate if any of these four things are missing. The basis of this protection method depends on the difference in corrosion potentials between the two metals immersed in the same electrolyte. This causes electrons to flow from the metal with the higher activity and negative potential (anode) to the metal with less activity and negative potential (cathode). This flow of electrons continues until the two metals are at the same potential, that is, there is equilibrium between the voltages. Electrode potential is a measure of the tendency for a material to be reduced e. g. accepts electrons. Also, activity is a measure of how easily a metal will give up electrons. Thus, the more active a metal is, the more negative the electrode potential. This principle, directly relates to the two types of cathodic protection systems: sacrificial anode systems – called passive protection and impressed current systems – also known as active protection.

Sacrificial anode systems are simple, require little but regular maintenance, and have low installation costs. We intentionally add a metal to the circuit to supply the electrons to the cathode. When metals are in a voltaic couple, the difference in there negative potentials causes the anodic metal to corrode and release metallic ions into the electrolyte. The more negativity in the corrosion potential means it will be a stronger reducing agent and will more readily give away electrons thus corroding first. Since the more negative metal in the closed circuit corrodes first, we can control corrosion by simply adding to the circuit a metal that possess two necessary characteristics: a corrosion potential more negative than the metal that is being protected, it is expendable which is not essential to the operation of any particular system. Therefore when a metal possessing these characteristics is made the anode, corrosion is controlled.

The impressed-current type of cathodic protection system depends on an external source of direct current. Alternating current cannot be used since the protected metal would likewise be alternating, between anodic and cathodic. Basically, the anode is immersed in the electrolyte is connected to one side of a DC power supply and the metal to be protected is connected to the other side. The voltaic current flow is detected and measure against a reference electrode. If unfavourable, current flow is adjusted automatically by the power supply control system to compensate. ' Due to the high currents involved in many seawater systems, it is not uncommon to use impressed current systems in marine situations. Impressed current systems use anodes (ICCP anode) of a type that are not easily dissolved into metallic ions, but rather sustain an alternative reaction, oxidization of the dissolved chloride ions' (Deepwater, 2012).

Advantages of this cathodic protection are that they can develop so much higher voltages than sacrificial anode systems, so they can either push current through lower conductivity electrolytes or through longer distances. Disadvantages include the possibility of over protecting certain metals. This can cause hydrogen embrittlement in high strength steels. In aluminium specifically, accelerated corrosion can occur of the very structure that is being protected. Therefore it is evident that this form of cathodic protection, although more complex, poses some reliable advantages as well as some detrimental disadvantages.