Conditions for iron corrosion

Aims of the experiment

- To investigate rust
- To investigate conditions under which iron rusts
- To describe the rusting of iron chemically

Principles

The word corrosion originates from the Latin word "corrodere" and means as much as corroded or gnawed away. The definition of the term "corrosion" is standardised. According to DIN 50900 Part 1 it reads: "Corrosion is the reaction of a metal material with its environment which causes a measurable change in the material and can lead to an impairment of the function of a metallic component or of an entire system."

"Rust" is usually referred to for the corrosion of iron in the air or in aqueous solutions. The first written records on rust originate from Plato (427 – 347 B.C.). He referred to rust as the earthy substance that exudes out of the metal.

Iron equipment that stands unprotected in the open air soon becomes covered with a red-brown layer of rust. As this can ultimately destroy the equipment, large quantities of iron and steel are destroyed annually. This gives rise to a considerable loss to the economy.

The purpose of this experiment is to clarify the conditions under which the corrosion of iron takes place.

It is known from everyday life that items consisting of iron, (e.g. cars, bikes, bridge parapets, etc.), which are exposed to wind and weather, start to rust.

The extent to which water or air, or water and air, influence the corrosion of iron will be investigated. The experiments will be carried out using iron wool.

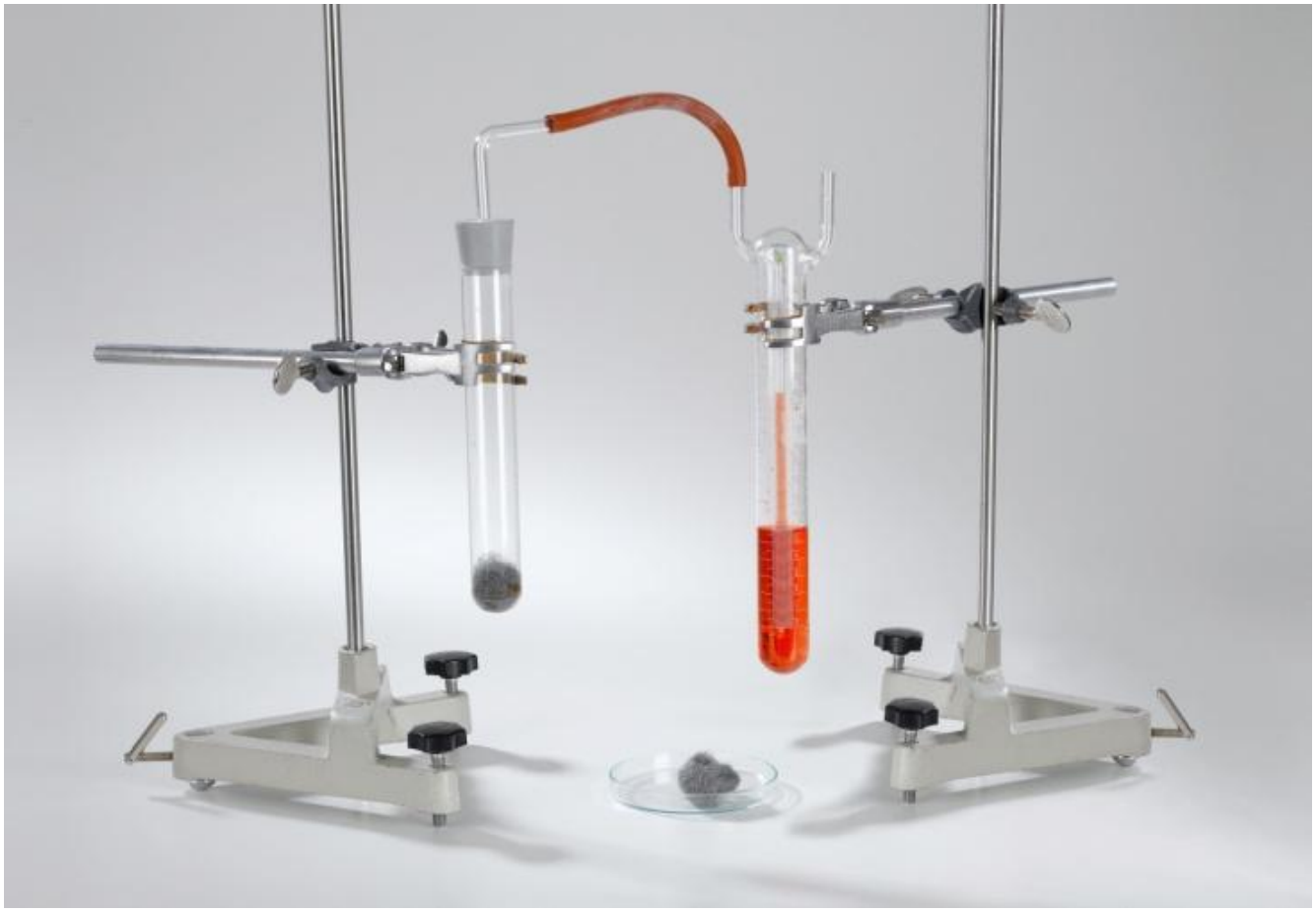

Fig. 1: Set-up of the experiment.

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Risk assessment

Petroleum ether is a mixture of various liquid hydrocarbons. It is a flammable liquid and must therefore be kept away from fire and similar sources of ignition. There is a danger of aspiration, so work with petroleum ether should only be done in a fume cupboard. Contact with the skin should be avoided, therefore protective rubber gloves should be worn. Further personal protective clothing should also be worn (goggles, lab coat).

Petroleum ether, 90 °C - 100 °C

Signal word:
HAZARD

Hazard statements

H225 Highly flammable liquid and vapour.

H304 May be fatal if swallowed and enters the airways.

H315 Causes skin irritation.

H336 May cause drowsiness or dizziness.

H411 Toxic to aquatic life with long-lasting effects.

Precautionary statements

P101 If medical advice is needed, have product container or label at hand.

P102 Keep out of reach of children.

P103 Read label before use.

P210 Keep away from heat/sparks/ open flames/hot surfaces. No smoking.

P260 Do not breathe vapours/spray.

P262 Do not get in eyes, on skin, or on clothing.

P243 Take precautionary measures against static discharge.

P301+ P330 + P331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.

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P403+P233 Store in a well ventilated place. Keep container tightly closed.

Equipment and chemicals

1	Schiele immersion tube manometer	665 936
1	Test tube holder, 10 tubes	667 054
4	Test tube, diam. 30 mm, set of 10	664 045
1	Angled tube 90°, 50/50 mm, 8 mm diam.	665 232
1	Rubber stopper, one 8 mm diam. hole	667 261
1	PVC tubing	667 180
2	Stand base, V-shaped	300 02
1	Stand rod 45 cm, 10 mm diam., set of 2	301 28ET2
2	Bosshead S	301 09
2	Universal clamp 0...80 mm	666 555
1	Petri dish, glass, diam. 100 mm	664 183
1	Tweezers, blunt, 145 mm	667 0344
1	Beaker, Boro 3.3, 250 mL, squat	664 130
1	Hot plate	666 767
1	Double-ended spatula, stainless steel, 150 mm	666 962
1	Iron wool, 50 g	671 8400
1	Petroleum ether, 90°C - 110°C, 250 mL	670 8200
1	Dye	309 42
1	Glycerine, 99%, 100 mL	672 1200
	Tap water, carbonated mineral water	

Set-up and preparation of the experiment

Preparation

With tweezers, remove four hanks of iron wool, each the size of a hazelnut. Then form them into small balls. Under the fume cupboard, put some petroleum ether into a Petri dish. Immerse the iron wool balls in this, turning them several times to degrease the iron wool, as grease on a metal surface acts as rust protection. When they are well soaked in petroleum ether, take them out with the tweezers and let them dry under the fume cupboard.

Label four test tubes with the numbers 1, 2, 3 and 4.

Insert the angled tube into the stopper according to Figure 1. Lubricate the angled tube beforehand with glycerine so that it slides more easily into the stopper.

Be sure to insert the glass tube carefully into the stopper - risk of injury!

Dissolve a spatula tip of dye in a beaker with distilled water.

Heat 100 mL of water in a beaker on the hot plate and let it boil vigorously for around 3 minutes. Then allow to cool.

Set-up of the experiment

Construct two stand structures from the stand materials according to Figure 1. Fill the immersion tube manometer half way with the dye solution. Fix the immersion tube manometer in the universal clamp.

Performing the experiment

Distribute the iron wool balls, which have been degreased in petroleum ether and dried, into the four test tubes as follows.

In tube 1, cover the iron wool with boiled water and place the tube in the test tube rack. Place an iron wool ball in tube 2 and cover it with mineral water. Tube 3 only contains the dry iron wool and is also placed in the test tube rack. Rinse tube 4 with tap water so that a few drops still remain in the tube. Then place the iron wool ball into the test tube and close the tube with a stopper containing the angled tube. Fix the test tube in the second stand construction. Connect the angled tube to the immersion tube manometer using a piece of tubing. Check the four test tubes for changes after about 30 minutes.

Observation

The iron wool in tube 1 shows no change.

In tube 2, the water becomes cloudy after a short time, and after a few hours the iron wool shows distinct red-brown spots.

In tube 3, the iron wool shows no change.

In tube 4, a slight rust appearance can be seen after 30 minutes. Distinct rusting can be seen overnight and the water column in the inner tube of the manometer also visibly rises.

Evaluation and result

No reaction occurred in tube 1. No rust formation occurs in the boiled water. Through boiling, the water is degassed. This prevented the iron reacting to form iron hydrogen carbonate. Iron does not rust in non-carbonated water.

In tube 2 containing carbonated mineral water, rust formation occurs.
In an acidic medium (mineral water contains carbon dioxide), acid corrosion can occur. This is termed a redox reaction.

Oxidation:

$$\overset{0}{Fe_{(s)}} \rightleftharpoons \overset{+II}{Fe^{2+}} + 2e^-$$

Reduction:

$$\overset{+I}{2\,H_3O^+} + 2e^- \rightleftharpoons \overset{0}{H_2} + 2\,H_2O$$

Overall reaction:

$$\overset{0}{Fe} + \overset{+I}{2\,H_3O^+} \rightleftharpoons \overset{+II}{Fe^{2+}} + \overset{0}{2\,H_2} + 2\,H_2O$$

In tube 3, no reaction occurred. Air alone is not responsible for rust formation.

In tube 4, air and water acted upon the iron simultaneously and rust formation was the result. Oxygen gas is consumed in rust formation, recognisable by the reduced pressure in the apparatus. This is a case of oxygen corrosion.

A redox reaction also occurs in the case of oxygen corrosion. The iron is oxidised and the oxygen is reduced. The rusting process can be broken down into the following partial reactions:

Oxidation:

$$\overset{0}{Fe_{(s)}} \rightleftharpoons \overset{+II}{Fe^{2+}_{(aq)}} + 2e^-$$

Reduction:

$$\overset{0}{O_{2(aq)}} + 2\,H_2O + 4e^- \rightleftharpoons \overset{-II}{4\,OH^-_{(aq)}}$$

Overall reaction:

$$\overset{0}{2\,Fe} + \overset{0}{O_2} + 2\,H_2O \rightleftharpoons \overset{+II}{2\,Fe(OH)_2}$$

The $Fe(OH)_2$ (iron hydroxide) formed precipitates out.

The moist iron(II) hydroxide is unstable in the presence of oxygen. It reacts further with oxygen to form iron(III) oxide ($Fe_2O_3 \cdot x\ H_2O$) in the presence of water. This compound is called rust.

$$\overset{+II}{4\,Fe(OH)_2} + \overset{0}{O_2} \rightleftharpoons \overset{+III\ -II}{2\,Fe_2O_3} + 4\,H_2O$$

Corrosion can occur in different manifestations. There is surface corrosion; here the corrosion occurs as a parallel layer on the surface of the metal. If it is only localised, it is referred to as pitting corrosion. Also to be mentioned is inter-crystalline corrosion. Here, the corrosion takes place along the grain boundaries. It occurs primarily in alloys.

Cleaning and disposal

Place the petroleum ether in a waste container for organic solvents. The iron wool ball can be disposed of in the household waste. The dye solution can be poured down the drain. It should be rinsed away thoroughly.