

## Experiments with the corrosion set

### Aims of the experiment

- To demonstrate the corrosion of metals
- To demonstrate the behaviour of various metals in electrolytes
- To demonstrate acid corrosion of various metals

### Principles

To be understood by the term corrosion is the undesirable reaction of a material with its environment (e.g. water or oxygen) which slowly leads to its destruction. Corrosion damage has a far-reaching effect on the economy.

Most metals are oxidised in water or air, thereby returning to their original stable state. They are converted to their ionic state and form compounds such as oxides or sulfides from which they were originally obtained industrially with the consumption of energy.



The entire corrosion process depends on the metal concerned and on the environment (e.g. the medium or reaction partner).

Metals dissolve in acids. In an acid medium with a sufficiently high concentration of  $\text{H}_3\text{O}^+$  ions, all metals with a negative standard electrode potential can in principle be attacked. But even naturally occurring weak acids such as rain containing, for example, carbon dioxide with a pH value of 5 - 6 can

damage unprotected metals over the course of time - even more so "acid rain" containing sulfuric and nitric acids with a pH value of 4 and below. Combinations of different metals in electrically conductive contact have a particularly disadvantageous (corrosion-promoting) effect. The corrosion set will be used to demonstrate that acid corrosion has its origins in electrochemical processes. When different metals are present concurrently in an electrically conductive medium, such as dilute sulfuric acid, they generate an electric voltage. This voltage increases the further apart the metals are in the electrochemical series. Every metal can donate electrons to all other metals lower down in the electrochemical series and itself be converted to the ionic state. When a non-noble element is immersed in a solution containing the ions of a nobler element, the charge is removed from the ions; the nobler element is deposited as metal and the atoms of the less noble element go into solution as ions.

As a consequence of the current flow from the less noble metal to the nobler metal, decomposition of the less noble metal can be observed. The larger the potential difference between the two metals, the more intensive is this decomposition.

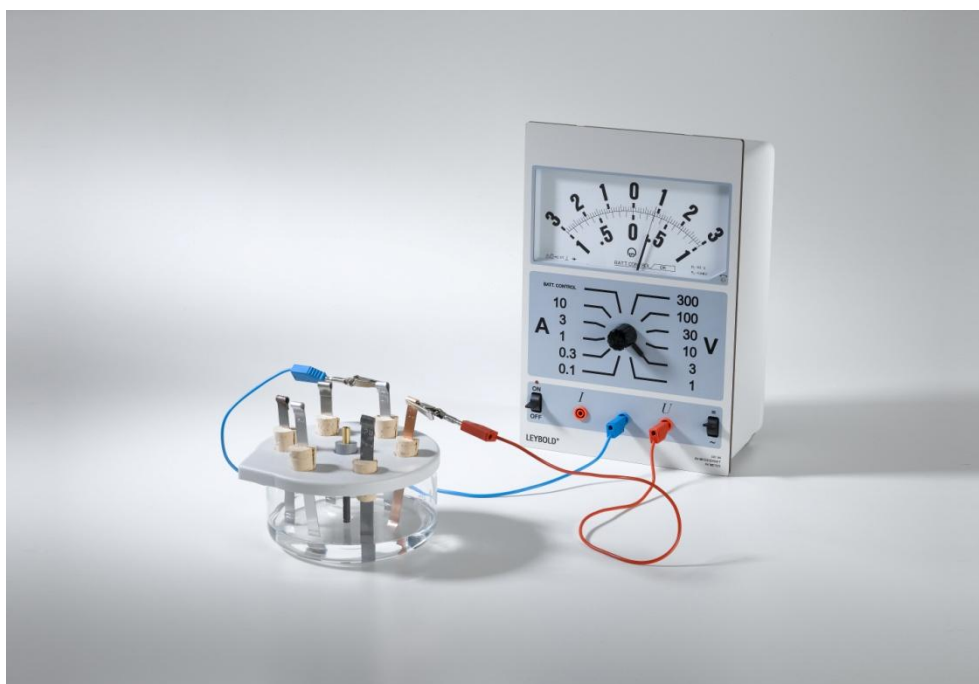



Fig. 1: Set-up of the experiment.

## Risk assessment

Sulfuric acid is corrosive at the concentration used in the experiment. Wear protective goggles and gloves when handling.

Sulfuric acid, dilute	
 <p><b>Signal word:</b> <b>Caution</b></p>	<p><b>Hazard statements</b></p> <p>H290 May be corrosive to metals. H315 Causes skin irritation. H319 Causes serious eye irritation.</p> <p><b>Precautionary statements</b></p> <p>P280 Wear protective gloves / eye protection. P305+P351+P338 IF IN EYES: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing. P337+P313 If eye irritation persists: Get medical advice/attention. P302+P352 IF ON SKIN: Wash with soap and water.</p>

## Equipment and chemicals

1 Corrosion Set.....	664 3561
1 AV meter.....	531 94
1 Connecting leads 50 cm, red/blue.....	501 45
1 Crocodile clips, polished, 6 pcs.....	501 861
1 Grindstones, set of 4.....	664 391ET4
1 Sulfuric acid, approx. 2 N (=10%), 500 ml	674 7920
1 Measuring cylinder 500 ml.....	665 756
1 Graduated pipette 10 ml.....	665 997
1 Pipetting ball.....	666 003
1 Glass stirring rod.....	665 212ET10

## Set-up and preparation of the experiment

### Set-up of the experiment

The corrosion set contains a set of seven electrodes, whereby the carbon electrode is a rod electrode. Rub the metal electrodes with a grindstone until they are shining clean. Then insert each electrode between two halves of a cork and press them into the cover. Fill the glass dish of the corrosion set about half full with 1 % sulfuric acid. (The sulfuric acid (674 7920) is 10% and is diluted 1:10 with water. This is done by placing 270 ml of water into the glass dish and pipetting in 30 ml of 10 % sulfuric acid. Mix the mixture with the glass stirring rod.)

Place the cover with the electrodes onto the glass dish so that the electrodes are immersed in the liquid.

Attach crocodile clips to one end of the connecting leads. Set up the AV meter next to the corrosion set (see Fig.1). Connect the blue lead to the ground connector of the AV meter and the red lead to the input socket for voltage measurement.

### Performing the experiment

1. Select the carbon electrode as the reference. Connect the carbon electrode to the red lead that is connected to the red input socket U on the AV meter. Using crocodile clips, clip the blue lead onto the zinc electrode, for example, and then insert

it in the blue ground socket of the AV meter. Switch on the AV meter and set it to direct current using the changeover switch. Select a suitable measurement range on the rotary selection switch.

2. Read off the value and note it down.

3. Repeat the procedure for the other electrodes.

In further experiments, the copper electrode, for example, can be used as the reference electrode.

## Observation

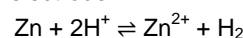
A distinct formation of gas can be observed at the zinc electrode shortly after immersing it in the acid. This takes place without having connected it to another electrode. No visible gas formation can be observed at the other electrodes.

The following values are measured on the AV meter:

Electrode pair	Potential difference [V]
C/Cu	0.35
C/Ag	0.25
C/Ni	0.40
C/Fe	0.85
C/Zn	1.30
C/Al	1.05

## Evaluation

The zinc electrode dissolves in the acid without being connected to a second electrode.



Hydrogen gas is created, which bubbles up on the electrode.

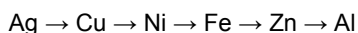
The combination of carbon and metal electrode produces different voltages, depending on the metal. Metals react differently in acids. This depends on their electrode potential.

If one places the metals in increasing order of the measured potential difference, this produces the following series:

Metal	Ag	Cu	Ni	Fe	Al	Zn
Potential difference [V]	0.25	0.35	0.40	0.85	1.05	1.30

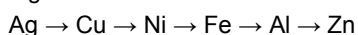
## Result

The following electrochemical series can be found in the literature for the metals:



The standard potentials given in the literature can only be realised using special equipment (e.g. the Electrochemistry Workstation 664 3951). In contrast, the actual corrosion is measured with the Corrosion Set. However, the relationship of the voltages of the various metals to one another is made particularly clear in this set-up.

From the potential differences of the metals used, the following series can be constructed in this experimental set-up:



In our experiment, aluminium reacts with a higher potential than that given in the literature. Only the surface of aluminium reacts with air and water at room temperature (passivation). This passivated oxide layer makes pure aluminium very corrosion resistant at pH values of 4 to 9.

If two metals touch one another and an electrolyte is added, the less noble metal is dissolved and the nobler metal remains intact.

The less noble metal, in our case zinc, has the greater tendency to convert to the more stable metal ions, or to possess valence electrons. Through this process, however, they leave behind electrodes on the metal which, because of the good electrical conduction properties, flow to the nobler metal. The outflow of electrons now has the effect that even more atoms of the less noble metal convert to the ionic form and the metal decomposes even further. The nobler metal then becomes negatively charged through the inflow of electrons, therefore no metal ions can be formed. A potential difference results.

#### **Corrosion protection**

There are several possibilities available to provide surfaces with corrosion protection. Covering the surface with an impenetrable protective layer (e.g. by painting) can prevent moist air from reaching the surface. This protection fails as soon as the protective layer becomes porous. The corrosion then continues under the paint layer. Another version of sur-

face coating is galvanising (e.g. coating the surface of iron with zinc). Many metal oxides are kinetically inert, i.e. they adhere to the surface of the metal and form an impermeable layer that is effective over a wide pH range. This is called passivation. In the case of cathodic corrosion protection, the object is bonded to another metal whose standard electrode potential is more negative than that of the object to be protected. For example, magnesium is used as a sacrificial anode. It donates its electrons to the iron and is itself oxidised in the process. However, a block of magnesium that needs to be replaced from time to time is much cheaper than the ship or the building or the pipeline that in this way is protected from corrosion.

#### **Cleaning and disposal**

Carefully pour the contents of the glass dish into the laboratory drain and wash it away with large amounts of water. Rinse the electrodes under running water and leave them to dry.