

## Electrochemical corrosion protection

### Aims of the experiment

- To learn about two methods of corrosion protection
- To understand the function of a sacrificial anode
- To carry out corrosion protection using direct current
- To work with the electrochemistry demonstration equipment

### Principles

To be understood by the term corrosion is the slow oxidation of metals under the influence of the surrounding medium. Metal corrosion can cause considerable damage to the economy. Rust damage to car bodies has been a frequent complaint in the past. Meanwhile, car bodies are better protected from penetrating rust through corrosion protection.

What is to be understood by corrosion protection are the various methods used to prevent corrosion. The metal is protected from air and water in this case.

Corrosion protection can be achieved through protective layers or by electrochemical means. In the case of electrochemical corrosion protection, the material can be protected by using a counter-electrode, a so-called sacrificial electrode. The sacrificial electrode for a metal to be protected consists of a less noble metal that is preferentially attacked, i.e. corroded, in place of the more noble metal. One possible alter-

native is electrochemical corrosion protection through applying a direct current.

These two possibilities of electrochemical protection will be presented in this experiment. In the first part of the experiment, the metal to be protected will be connected conductively to a less noble metal. A corrosion element is formed, whereby the less noble metal (the sacrificial anode) enters into solution and the more noble metal remains protected.

In the second part of the experiment, the metal to be protected is connected to the negative pole (the cathode) of a DC current source. In combination with a carbon electrode, a circuit is formed. The metal to be protected receives electrons from the current source and is thereby protected.

Both methods play an important role in the protection of ship hulls, harbour installations, pipelines, pipes and containers.

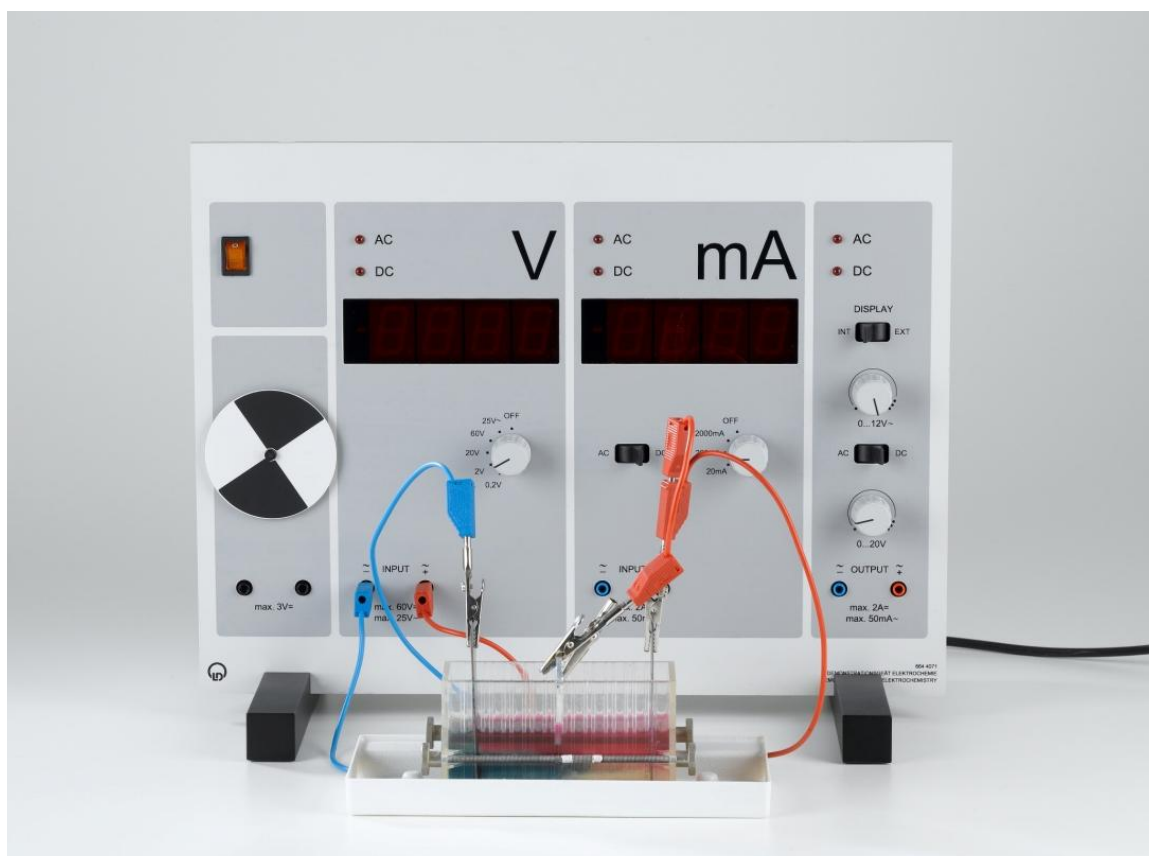





Fig. 1: Set-up of the experiment.

## Risk assessment

Magnesium is a flammable solid and must therefore be kept away from fire and similar sources of ignition. Avoid dust formation; do not inhale dust, do not smoke. Wash your hands after use. Personal protective clothing should be worn (goggles, lab coat). Phenolphthalein is dissolved in ethanol. Avoid the formation of vapour/aerosols. Keep away from sources of ignition, do not smoke. Take precautionary measures against static discharge. Do not leave containers open. Observe general hygiene measures and wear personal protective clothing (goggles, lab coat).

Magnesium, ribbon	
 <b>Signal word:</b> Caution	<b>Hazard statements</b> H228 Flammable solid.  <b>Precautionary statements</b> P370+P378 In case of fire: Use metal fire extinguisher / sand for extinction.
Phenolphthalein solution (contains ethanol)	
  <b>Signal word:</b> Hazard	<b>Hazard statements</b> H225 Highly flammable liquid and vapour. H350 May cause cancer. H341 Suspected of causing genetic defects.  <b>Precautionary statements</b> P210 Keep away from heat/sparks/open flames/hot surfaces. No smoking. P233 Keep container tightly closed. P281 Use personal protective equipment as required. P308+P313 If exposed or concerned: Get medical advice/attention.

## Equipment and chemicals

1	Electrochemistry demonstration unit, CPS.....	664 4071
1	Stand bases, pair.....	301 339
1	Electrochemistry accessory set.....	664 401
1	Compact balance 200 g : 0.01 g .....	667 7977
1	Volumetric flask Boro 3.3, 500 ml .....	665 795
1	Volumetric flask Boro 3.3, 100 ml .....	665 793
1	Dropping pipette, 150 x 7 mm, set of 10 .....	665 953
1	Rubber bulbs, set of 10.....	665 954
1	Spoon spatula, stainless steel.....	666 967
1	Scissors, 125 mm long.....	667 017
1	Funnel, PP. 50 mm diam. ....	665 008
1	Sodium chloride, 250 g .....	673 5700
1	Potassium ferricyanide (III), 50 g .....	672 6100
1	Magnesium, ribbon, 25 g .....	673 1000
1	Phenolphthalein solution, 1 %, 100 ml.....	674 2500

## Set-up and preparation of the experiment

### Preparing the solutions

A "corrosion indicator solution" will be prepared. This consists of a 10 % solution of NaCl, a 1 % solution of  $K_3Fe(CN)_6$  and a 1 % phenolphthalein solution.

*Preparing a 10 % NaCl solution:* Weigh out 50 g of NaCl and place it in a 500 ml volumetric flask. Fill the volumetric flask with distilled water up to the 500 ml mark.

*Preparing a 1 %  $K_3Fe(CN)_6$  solution:* Weigh out 1 g of potassium ferricyanide, place it in the 100 ml volumetric flask and fill the flask with distilled water to the 100 ml mark.

Put together two cell troughs from four half-cell blocks and join them together with the screws. During the experiment, place the cell trough in a drip tray.

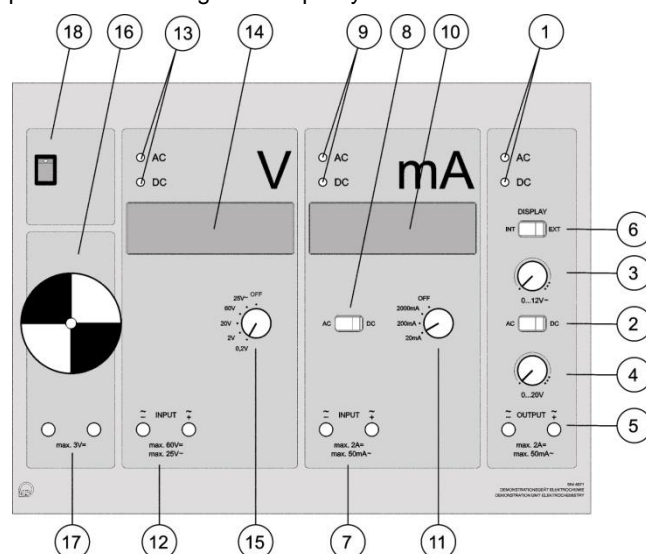


Fig. 2: The electrochemistry demonstration unit.

### Performing the experiment

#### Experiment a: Corrosion protection using a sacrificial electrode

- Place the electrochemistry demonstration unit into both stand bases, connect it to the mains supply and switch it on at the switch (18).
- Rub the iron electrodes with a rubber bulb until they are shining clean. From the magnesium ribbon, cut off a strip about 7 cm long.
- Fill the cell trough to a depth of 2 cm with 10 % NaCl solution. Add 1 %  $K_3Fe(CN)_6$  solution to a depth of 0.5 cm. Add about 10 drops of phenolphthalein solution using a dropping pipette and fill to the 4 cm mark with distilled water.
- Place the iron electrodes in the first recess from the edge in each case. Attach the strip of magnesium ribbon at the middle of the cell trough using an alligator holding clip. Observe and note down the processes that occur at the magnesium electrode and the iron electrode.
- Attach alligator clips to both ends of a red lead. Attach an alligator clip on the red lead to the projecting piece of the magnesium ribbon and attach the alligator clip at the other end to an iron electrode. Observe and note down the processes that occur at the electrodes.
- Now connect both electrodes to the voltmeter. Connect the blue lead with the alligator clip to the second iron electrode and the free end of the lead to the negative terminal of the voltmeter on the electrochemistry demonstration unit (12). With the red lead, create a connection between the positive

terminal of the voltmeter and the iron electrode that is connected to the magnesium electrode. Observe and note down the processes that occur at the electrodes. Read and note down the value on the voltmeter display (14).

7. Remove both leads from the voltmeter inputs and connect them to the input sockets (7) of the ammeter. Read and note down the value on the voltmeter display (10). Connect both cables to the input of the motor (17) and observe what happens.

#### Experiment b: Corrosion protection using direct current

1. Rub the iron electrodes with a rubber bulb until they are shining clean.

2. Place an iron electrode in each of the outer recesses of the second cell trough. Place an additional carbon electrode at around the centre of the cell trough.

3. Connect the carbon electrode and one of the iron electrodes to the socket (5) on the power supply output of the electrochemistry demonstration unit using two connecting leads, each of which equipped with an alligator clip. In this case, connect the carbon electrode to the positive terminal and the iron electrode to the negative terminal of the power supply output. Apply the leads in accordance with the colour coding of the sockets.

4. Set the power supply to direct current at the changeover switch (2) and also set the changeover switch on the ammeter (8) to direct current.

5. Switch on the electrochemistry demonstration unit and set a voltage of about 2 V using the rotary control (4) on the power supply.

6. Now fill the cell trough with the prepared corrosion indicator solution (see experiment a) to a depth of 4 cm. Ensure that the solution is distributed evenly around the cell trough. Raise the electrodes briefly, if necessary.

7. Observe and note down the processes that occur at the electrodes.

#### Observation

##### Experiment a: Corrosion protection using a sacrificial electrode

A blue colour appears at the iron electrodes upon insertion. As soon as the magnesium ribbon is immersed in the solution, gas is formed. When one of the iron electrodes is connected to the magnesium electrode, the blue colour recedes and disappears completely. Here a slight formation of gas appears and a red colour occurs additionally at the iron electrode.

The blue colour remains at the other iron electrode and corrosion occurs. No blue colour can be seen at the iron electrode that is connected to the magnesium electrode. On connecting the magnesium electrode and the iron electrode to the voltmeter, the polarity can be read. A corrosion current flows between the magnesium electrode and the unprotected iron electrode and a corrosion voltage (750 mV) and current (43 mA) can be measured. The magnesium electrode dissolves after a longer period of time.

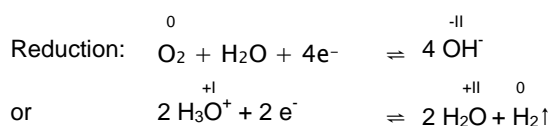
##### Experiment b: Corrosion protection using direct current

At the iron electrode without an applied direct current, a blue colour occurs immediately. At the other iron electrode that is connected to the power supply, a red colour occurs. No reaction can be seen at the carbon electrode.

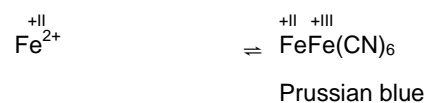
#### Evaluation and result

Evidence for the fact that iron(II) ions have entered into solution is provided by the corrosion indicator solution. They form the compound "Prussian blue" with the potassium ferricyanide. "Prussian blue" has a bright blue colour.

Corrosion of iron:



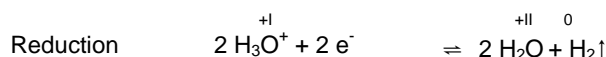
Formation of "Prussian blue"



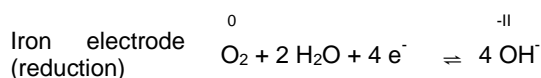
##### Experiment a: Corrosion protection using a sacrificial electrode

If an electrically conductive connection is made between iron and a less noble metal, the iron can be protected against corrosion.

When the magnesium ribbon is immersed in the indicator solution, it dissolves with the formation of hydrogen (gas bubbles).



If an electrically conductive connection is made between the magnesium electrode and the iron electrode, the electrons released from the magnesium migrate to the iron (instead the hydrogen). Oxygen is reduced at the iron electrode. The iron itself does not dissolve.



By connecting the electrodes to the voltmeter, the polarity can be displayed. The iron electrode is the positive pole and the magnesium electrode the negative pole. The magnesium electrode dissolves slowly.

A voltage of 750 mV can be measured. When short-circuited across the ammeter, a current of 43 mA flows. This makes it possible to drive the motor to be driven for illustration purposes.

The magnesium electrode serves as a sacrificial anode. It dissolves and protects the iron electrode connected to it from corrosion. The iron electrode does not dissolve. The electrons from the magnesium electrode prevent oxidation of the iron electrode. In the case of corrosion protection using a sacrificial anode, the less noble metal goes into solution and the more noble metal is protected.

##### Experiment b: Corrosion protection using direct current

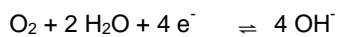
A blue colour is to be seen at the iron electrode without the applied DC voltage, therefore corrosion occurs. In contrast, a

red colour can be seen in the liquid at the iron electrode which is connected to the DC voltage source together with the carbon electrode. Therefore no corrosion occurs. The corrosion of iron



is prevented, as electrons are supplied from the electrical circuit instead of from the iron.

The reduction reaction



continues to occur and causes an increase in the pH value.

The indicator phenolphthalein is colourless in the acid range. At a pH value of 8.2 - 10.0, the colour turns red. For this reason, an alkaline pH value is shown at the iron electrode.

### **Cleaning and disposal**

Place the solutions into the container for organic solutions.

Rinse the electrodes and the troughs well and allow them to dry.