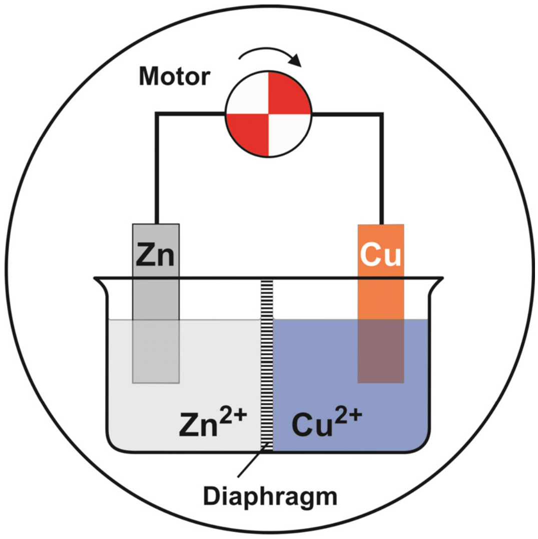
DANIELL Cell



Equipment:

clay flowerpot
rubber stopper
crystallizing dish
copper electrode
zinc electrode
high-impedance voltmeter
small electric motor
    with white-red card board disc
ring stand, bosshead
cables

Chemicals:

copper sulfate solution (1 kmol m^{-3})
zinc sulfate solution (1 kmol m^{-3})
saturated sodium chloride solution

Safety:

copper(II) sulfate pentahydrate ($CuSO_4\,5H_2O$):

H302, H315, H319, H410
P273, P305 + P351 + P338, P302 + P352

zinc(II) sulfate heptahydrate ($ZnSO_4\,7H_2O$):

H302, H318, H410
P280, P273, P305 + P351 + P338

It is required to wear safety glasses and protective gloves; if possible, the experiment should be carried out in a fume hood.

Procedure:

Preparation: The flowerpot, the bottom of which has been tightly sealed with the rubber stopper, is soaked from the day before in the saturated sodium chloride solution. Shortly before the experiment, it is removed from the saline solution, rinsed off and placed in the crystallizing dish. The electric motor is attached to the ring stand and the electrodes are cleaned if necessary.
Procedure: The zinc sulfate solution is filled into the crystallizing dish and the copper sulfate solution into the flowerpot. Subsequently, the copper electrode is immersed in the copper sulfate solution and the zinc electrode in the zinc sulfate solution. The electrodes are first connected to the voltmeter. Subsequently, the electric motor is connected in parallel to the voltmeter.

Observation:

A voltage of just over 1 V can be read off the voltmeter. The motor is running, clearly recognizable by the rotation of the disc; however, the voltage drops.

Explanation:

In the case of the reaction

$$Cu^{2+}|w + Zn|s \rightarrow Cu|s + Zn^{2+}|w,$$

the two half-reactions

$$\begin{array}{l} Zn \rightarrow Zn^{2+} + 2\,e^{-} \\ Cu \leftarrow Cu^{2+} + 2\,e^{-} \end{array}$$

can also be spatially separated from each other by dividing them into the two half-cells of a galvanic cell where they are connected to each other by an exterior circuit. The so-called DANIELL cell is composed of a Zn and a Cu electrode that are immersed in corresponding Zn^{2+} or Cu^{2+} solutions whereby these electrolyte solutions are in contact with each other through a diaphragm. In the present experiment, the clay wall of the flowerpot assumes the role of the diaphragm.

The gradient of the chemical potential continues to drive the reaction in question, however, the reactants can no longer reach each other so easily because they are separated by a "wall" (the electrolyte solutions) that ions can permeate but electrons cannot. The only possibility is for the ions and electrons to go "separate ways." While the ions can migrate into the electrolyte solution, the electrons must be diverted through the external circuit. Zinc ions at the zinc electrode go into the solution, meaning that oxidation takes place, so we know we are dealing with an anode. The accumulation of electrons caused by the electrons left behind, gives this electrode a negative charge. At the copper electrode, on the other hand, copper ions are deposited in the form of neutral copper. This means that the ions are reduced (cathode). The "electron suction" caused by the consumption of electrons gives this electrode a positive charge. Consequently, an electric voltage develops between the two electrodes. However, immediately after even extremely small amounts of ions have transferred, electrochemical equilibrium is already established at the electrodes.

The voltage of the DANIELL cell measured in equilibrium (meaning for zero current flowing) and under standard conditions ($T^{\ominus}$ = 298 K, $p^{\ominus}$ = 100 kPa, $c^{\ominus}$ =1 mol×m^{-3}) corresponds theoretically to the difference of the cathode and anode potentials:

$$\Delta E^{\ominus} = -U = E^{\ominus}(Cu/Cu^{2+}) - E^{\ominus}(Zn/Zn^{2+}) = +0.3402\text{ V} - (-0.7628\text{ V}) = +1.103\text{ V}.$$

ΔE is also called "reversible cell voltage."
Experimentally, an "open circuit voltage" of just over 1 V is measured.

The chemical reaction (divided into two partial reactions) can be used to drive an electron current in the external circuit. In this way, for example, a small electric motor with a white-red card board disc (to show the motion) can be driven. The DANIELL cell thus enables the direct conversion of chemical energy into electrical energy. However, the electric voltage drops when the current flows through a load because the electrochemical equilibrium is disturbed.

Disposal:

The zinc sulfate and copper sulfate solutions may be stored for further experimental purposes provided they have not been contaminated too much. Otherwise, the solutions are collected in the container for heavy metal waste.