Physical Chemistry

Electrochemistry

Conductivity and ions

LD Chemistry Leaflets

C4.4.1.7

Conductivity of solutions

Time required: 45 min

Aims of the experiment

- To recognise that ions are necessary to conduct electricity in a solution.
- To show that pure water does not conduct electricity.
- To show that many organic solvents also do not conduct electricity.
- To define ions as charge transporters.
- Basics of electrolytes and dissociation.
- Definition of weak electrolytes.

Principles

In contrast to solids in which a current transport is achieved through electrons (1st order conductor), in liquids the only charge transport possible is through ions (2nd order conductor). Ions can be already present in a liquid or can be introduced to the solution through dissolution of a substance into the solvent.

The more charged particles are present, the greater the conductivity in general. However, dissolved substances which do not produce ions, such as sugar, do not increase the conductivity of a solution. The same applies for incompletely dissociated substances such as acetic acid. A major portion of the acetic acid molecule does not take part in the conduction.

The conductivity also depends on the mobility of the dissolved particles.

In this experiment, various aqueous liquids will be tested for their conductivity. The electric current will be measured. It will also be shown whether or not electric current is flowing in the system based on the movement of the motor. In addition, a semi-quantitative conclusion will be made about the electrolyte characteristics of the solution.

Fig. 1: Set-up of the experiment and materials.

Risk assessment

CAUTION! Do not select a higher voltage since otherwise the maximum allowable current of 2000 mA will be exceeded and a short circuit may occur.

Do not bring the electrodes together.

When working with acids and bases: wear goggles and a lab coat.

Ammonia solution, 2 mol/l

Signal word:

Caution

Hazard warnings

H318 Causes serious eye damage.

H315 Causes skin irritation.

Safety information

P280 Wear protective gloves/protective clothing/eye protection/face protection.

P305+P351+P338 IF IN EYES: Rinse carefully with water for several minutes. Remove contact lenses if present and if possible to do so. Continue rinsing.

P310 Call a POISON CENTER or doctor/physician immediately.

P302+P352 IF ON SKIN: Wash with a large quantity of water.

P362 Remove contaminated clothing and wash before wearing again.

P332+P313 In case of skin irritation: Get medical advice/attention.

AA-2018-07

Sodium hydroxide solution, 0.1 mol/L	
 **Signal word: Caution**	**Hazard warnings** H290 May be corrosive to metals. **Safety information** P390 Absorb spillage to prevent material damage.

Hydrochloric acid, 0.1 mol/l	
 **Signal word: Caution**	**Hazard warnings** H290 May be corrosive to metals. **Safety information** P390 Absorb spillage to prevent material damage.

Equipment and chemicals

1 Electrochemistry demonstration unit, CPS.....664 4071
1 Panel frame C50, two-level, for CPS 666 425
1 Electrochemistry table, CPS 666 472
1 Electrochemistry accessories set...................664 401
2 Half cells (1 trough)................................ from 664 401
2 Nickel electrodes.................................... from 664 401
2 Connecting leads, 25 cm .... from 664 401
1 Drip pan .... from 664 401
4 Pasteur pipettes...665 950
4 Rubber bulbs..665 954
1 Water, pure, 1l 675 3400
1 Ammonia solution, diluted, 2 mol/l, 500 ml.....670 3650
1 Acetic acid, diluted, 0.1 mol/l, 1 l...................671 9570
1 Hydrochloric acid, diluted, 0.1 mol/l, 1l...........674 6960
1 Sodium hydroxide solution, 0.1 mol/l 673 8410
1 Sodium chloride, 500 g 673 5710
1 Saccharose, 250 g.......................................674 6060

Set-up and preparation of the experiment

Preparation of the experiment

Combine two half cell blocks into one electrolysis cell.

Place one nickel electrode in each of the two outermost grooves of the electrolysis cell. Then, set the electrolysis cell prepared as described with the drip pan onto the tray of the demonstration unit. Connect one output socket of each power supply (5) to a nickel electrode using a gripping clamp. At the power supply, set the changeover switch (2) to the AC (alternating current) position, and do the same for the changeover switch on the measuring unit (8). Turn on the measurement display of the power supply (selector switch (6)) (see Fig. 2).

Performing the experiment

Prior to the measurement add tap water and fill up to about the 2 cm mark on the electrolysis cell. Insert one nickel electrode into each outer groove.

Now connect the electrodes to the demonstration unit as explained in Fig. 3. After turning on the equipment, set a voltage of 10 V using the control dial. The alternating current of 10 V does not need to be readjusted before each measurement.

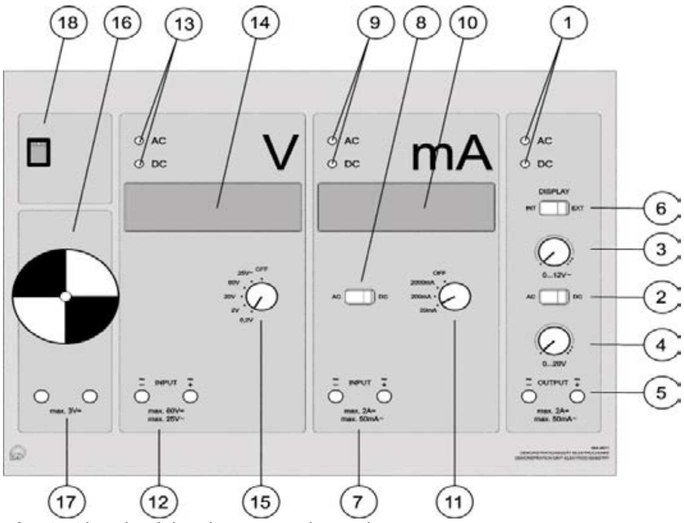

Fig. 2: Sketch of the demonstration unit.

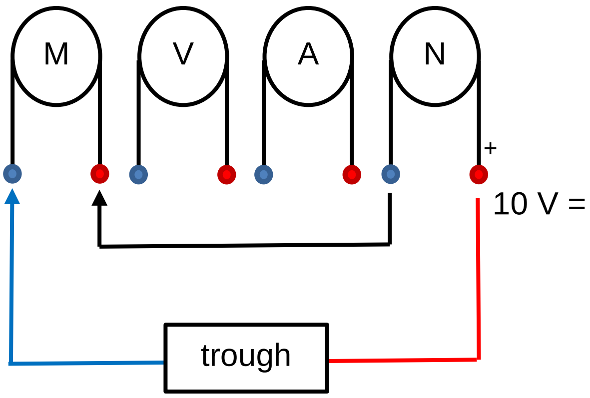

Fig. 3: Circuit for the experiment.

Tabulate the indicated current and take a note of whether or not the electric motor has moved. At the end of the test, thoroughly rinse the electrolysis cell and the electrodes with distilled water.

Now proceed in the same manner with the remaining solutions.

0. Tap water
1. Distilled water
2. Ethanol
3. Dist. water + 2 ml of diluted acetic acid
4. Dist. water + 2 ml of diluted ammonia solution
5. Dist. water + a small amount of household sugar
6. Dist. water + 2 ml of diluted hydrochloric acid
7. Dist. water + 2 ml of diluted sodium hydroxide solution
8. Dist. water + a small amount of sodium chloride (NaCl)

Turn off the demonstration unit at the end of the experiment.

Observation

The following Table 1 contains the currents and observations resulting from the experiment.

Tab.1: Indicated current and reaction of the electric motor.

	Liquid	Current (mA)	Motor
0	Tap water	3.8	low
1	Water, pure	0	off
2	Ethanol	0	off
3	Acetic acid	2.8	off
4	Ammonia solution	2.2	off
5	Saccharose solution	0	off
6	Hydrochloric acid	26.8	strong
7	Sodium hydroxide solution	47.2	very strong
8	Sodium chloride solution	42	very strong

Evaluation

In this experiment, non-electrolytes, weak electrolytes and strong electrolytes will be tested for their ability to conduct an electric current. The measurements obtained can be classified into 3 groups.

Group 1: Liquids that to not move the motor and where no current is measured. This includes water, ethanol and a saccharose solution.

Group 2: Liquids that also do not move the motor, but in which a small current is indicated. This includes tap water, acetic acid and the ammonia solution.

Group 3: Liquids that move the motor and that indicate a strong current. This includes hydrochloric acid, the sodium hydroxide solution and the sodium chloride solution.

Results

In general, electrolytes are subdivided into these three categories.

1. Non-conducting liquids (non-electrolytes)

This includes liquids that contain no ions or other charge carriers at all.

The liquids do not possess any ions (for example in benzine, hexane, saccharose solution) or the number of ions is too low (ethanol) to cause any measurable conductivity. In H_2O (pure) only one out of 5,555,555,555,555,555 molecules dissociates! And since water is for the most part undissociated (into hydroxide and oxonium ions), electrical charges cannot be transported through the liquid to any appreciable extent.

2. Weakly conducting liquids (weak electrolytes)

Weak electrolytes include liquids that can only conduct electrical current very moderately at currents of 1-10 mA.

Tap water (and weak acids and bases such as acetic acid and ammonia solutions) are such weak electrolytes.

These liquids either possess a certain amount of ions due to traces of dissolved salts (tap water that has calcium and magnesium in it, as well as other ions) or the liquids are weakly dissociated acids and bases. It is now possible to conduct a current through these liquids. The reason is the existence of different charges in the liquid due to the dissolved salts in tap water. During dissociation, anions and cations are formed at the same time and they are differently charged; therefore they move towards an anode or cathode.

3. Strongly conducting liquids (strong electrolytes)

Strong electrolytes include liquids that can conduct electrical current well or very well, with currents of > 10 mA.

Strong acids and bases (such as hydrochloric acid and sodium hydroxide solution) as well as dissolved salts (such as sodium chloride, curing salt (potassium nitrate), natural (Chile) saltpetre) are such strong electrolytes.

These liquids either possess a certain amount of ions due to dissolved salts or the liquids are strongly dissociated acids and bases. It is possible to conduct current through these liquids. The reason is the existence of different charges in the liquid due to the dissolved salts (NaCl, KNO_3, etc.) in distilled water. During dissociation, anions and cations are formed at the same time and they are differently charged; therefore they move towards an anode or cathode (faster than in weak electrolytes).

The stronger the degree of dissociation, the larger the conductivity of the liquid. Therefore, the conductivity can be used as a measure of concentration and degree of dissociation, as well as a measure of differentiation between electrolytes, for example it can be used to determine the salt content of waters or mineral waters, etc.

Cleaning and disposal

All solutions can be disposed of in the laboratory sink with plenty of water. Electrodes and half cell blocks must be rinsed and dried thoroughly.