Investigation of the Temperature Dependence of Conductivity of Electrolytes

Compounds which are decomposed to ions being dissolved or melted are called electrolytes. Examples of these are salts, acids, and bases. Decomposition of molecules to ions upon dissolving is called electrolytic dissociation. The degree of dissociation β shows the fraction of the compound which is turned into ions. Strong electrolytes have the degree of dissociation close to 1; weak electrolytes have β ≈ 0. Dissociation occurs due to interaction between the electrolyte and polar solvent molecules (polar molecules are those possessing a constant electric dipole moment; and example is water molecules). Electrolytic dissociation is a reversible reaction (such as $HCl \leftrightarrow H^+ + Cl^-$). Ions appearing in this reaction interact with solvent molecules. With water they form hydrates of constant or variable composition, such as H_3O^+ (hydronium ion).
Charge carriers in electrolytes are charged parts of molecules: cations and anions (positive and negative ions, respectively). The current density in an electrolyte containing ions of two types is defined as

$$j = \beta n(b_+ + b_-)eE\,, \qquad (1)$$

where n is the number of electrolyte molecules per unit volume (concentration), $(b_+ + b_-)$ is the sum of mobilities of cations and anions, E is the intensity of the electric field, and e is the charge of the cation.
Resistance of an electrolyte decreases as the temperature rises, since heating increases the dissociation degree and ion mobility. The temperature dependence of an electrolyte can be shown by the following formula:

$$R = R_0\left[1 - \alpha(t - t_0)\right], \qquad (2)$$

where R_0 is the resistance at the temperature t_0, R is the resistance at the temperature t, and α is the temperature coefficient of resistance (which can be assumed a constant in a narrow temperature range).

Experimental setup

In this work the temperature dependence of the resistance R of a aqueous solution of NaCl is studied. The solution is poured into a glass tube with two electrodes and a thermometer. Heating is achieved by a wire wound around the tubes and connected to the power mains. The resistance is measured with the aid of a Wheatstone bridge working on alternating current (Fig. 1); here AB is the sliding wire (rheochord) with resistance of the shoulders R_1 and R_2 proportional to their lengths AC = l_1 and CB = l_2. Point C is the rheochord's slider, R_m is the resistance box. One diagonal of the bridge contains a sound generator SG. Telephone T is connected to the other diagonal and works as the indicator of the balance in the bridge.

The balance is achieved at such a position of the contact C when the sound going out from the telephone is the weakest (in an ideal case it disappears). To define this point as accurate as possible, the resistance R_m in the box should be set so that the balance occurred when C is approximately in the middle of the wire. The resistance R being determined is then

$$R = R_m \frac{R_1}{R_2} = R_m \frac{l_1}{l_2}. \qquad (3)$$

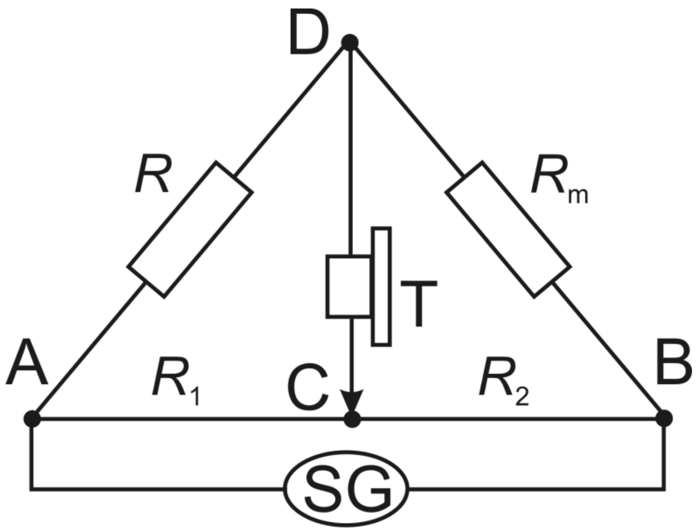

Figure 1.

Algorithm of measurements

1. If necessary, assemble the circuit according to the scheme in Figure 1. Turn on the sound generator SG by quickly pressing the knob. Find the balance: choose appropriate R_m in the box so that sound disappears with the slider C not too close to the ends of the wire. Write down the resistance R_m and the room temperature t. Measure the bridge shoulders l_1 and l_2 and find the resistance of the solution R_x using Eq. (3).
2. Connect the other tubes with the key and repeat the procedure in step 1. (*)
3. Turn on the heater and measure the resistances of the electrolytes in steps of 5–10° until the temperature achieves 90°C.
4. Turn off the heater. Repeat the measurements in steps 1-2 upon cooling until the temperature fall to ~30°C.
5. Build the plots $R = f_1(t)$ based on your experimental data.
6. Divide the measuring temperature range (20–90°) into 6–10 equal intervals Δt_i. For each of these intervals define the initial and final resistances R_{0i} and

R_i and calculate the coefficient α_i using the formula

$$\alpha_i = \frac{R_{0i} - R_i}{R_{0i}(t_i - t_{0i})}.$$

7. Build the dependence $\alpha = f_2(t)$.
8. Explain obtained dependences.

Notes

1. Using alternating current in this work is caused by the fact that use of DC would lead to electrolysis processes, polarization of electrodes, modification of the chemical composition of the solution of appearance of inhomogeneities in the liquid. Measured value of the resistance in this case would differ from the true value.
2. The view of the apparatus may not coincide with the scheme in Figure 1.
3. The task may be altered by the teacher. (*)

Questions

1. Charge carriers in electrolytes.
2. Electrolytic dissociation, degree of dissociation.
3. Conductivity of electrolytes, its temperature dependence.
4. Measuring the resistance of a conductor with a Wheatstone bridge. Justify the use of AC in the experiment.
5. Explain obtained results and the method of their processing.