COMMUNICATIONS

THE DC CONDUCTION MECHANISM OF ETHYLENE GLYCOL WATER SOLUTIONS

Dorota Nowak-Woźni — Tadeusz Mączka *

The effect of temperature and water content in ethylene glycol water solutions upon the electrical characteristics was studied in some details. The temperature was raised from room temperature up to about 380 K. It was suggested that the dependence between conductivity and temperature could be described by an exponential relation with the exponent depending on the potential barrier and temperature. It was supposed that the calculated potential barrier (0.2 eV to 1.1 eV) was associated with the motion of OH-groups.

Key words: DC conduction, potential barrier, charge transport, ethylene glycol

1 INTRODUCTION

Ethylene glycol and its water solutions are often used as a heat carrier in the industry. Ethylene glycol has good solubility in water. To obtain a solution with the best parameters, dielectric relaxation of ethylene glycol-water mixtures was performed over the whole concentration range at room temperature. The dielectric relaxation behaviour of mixtures of polar molecules under varying composition has attracted considerable interest because it helps formulating adequate models of liquid relaxation and also obtaining information about the relaxation process in the mixture [1–10]. These dielectric relaxation studies confirmed that the relaxation time of the system had a linear behaviour with the mole fraction of water in the mixture. It was also concluded that ethylene glycol (EG) molecules and surrounding water molecules formed EG-water clusters via hydrogen bonds and the nature of homogeneous and heterogeneous clusters changed with the water concentration in the binary mixture. Several attempts were made [11–21] to study the dielectric behaviour of various homologous series of alcohol mixtures with water and other polar solvents. At room temperature only one relaxation peak is observed for alcohol-water mixtures in the frequency range from 10 MHz to 20 GHz. The dielectric relaxation process of these systems is described by a sum of the Debye equation [22] and the Cole-Cole equation [23]. Though alcohol is the most popular material employed to study the hydrogen-bonding molecular liquids, it has been investigated systematically for only a few different alcohols. Experimental results of these binary systems are interpreted on the basis of a model of three kinds of cooperative domains coexisting in the mixtures.

The interest in the study of electric properties of glycol-water mixtures results from practical reasons. The glycol-water mixture is a potential material for applications in electro heating devices. The goal of this work is to obtain glycol and water solutions with relatively low resistivity. Then dielectric parameters of different solutions of water and glycol were measured.

2 EXPERIMENTAL

The materials used for making the mixtures were pure ethylene glycol and deionized water.

All these experiments were carried out at temperatures in the range from 293 K to 373 K. The temperature was controlled thermostatically within ±1 degree. Compositions and symbols for mixtures are presented in Table 1. Such mixtures allow a wide range of working temperatures as a technical point of view. The experiment was carried out in the unit presented in Fig. 1.

In the experiments, two rectangular plate electrodes were used. The rectangular plate electrodes were made of acid resistant steel. The electrodes are 0.105 m high and 0.062 m wide and are parallel to each other. The distance between the electrodes was kept by two Teflon plates. During the experiment the electrode surface temperature was measured in three points by thermocouple elements, type K, with a 0.25 mm diameter and LUTRON, type TM-906 A measurement equipment. The samples used in experiments were solutions of glycol (Table 1). The volume of each sample was 1 dm$^3$. During the experiments, the air pressure was almost normal, the temperature was 295 K, and the relative humidity was about 45%. The resistance of electrodes and wires was more than 50 MΩ. The measurements of sample resistivity were carried out with a MOTECH type MT 4080A RLC electronic meter. During the measurements the sample was under 1 V DC voltage and the resistance was measured after 60 s.

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Electrical measurements were made when the temperature in the thermal chamber was constant with accuracy ±1 degree. The temperature was raised from room temperature up to the moment when intensive evaporation was observed.

3 RESULTS

Temperature variations of the conductivity of single samples (different ethylene glycol and water contents) were examined. The results are presented in Fig. 2. It is important that the conductivity was determined on samples (different ethylene glycol and water contents). The calculated potential barrier for pure water is by at least one order of magnitude lower than the dissociation energy.

It is difficult to explain why the potential barrier in the middle temperature range is higher than in the other regions. Probably there are two different conduction mechanisms. One mechanism is the motion of OH-groups and the other one is the motion of monomer units [27].

4 CONCLUSIONS

Measurements have been performed of the resistivity of different ethylene glycol water solutions. This work is a starting point for studying the conduction mechanism in ethylene glycol water solutions. These preliminary results obtained are promising and it seems that the direction of the research is right and proper.

REFERENCES

<table>
<thead>
<tr>
<th>Mixture content</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>Pure ethylene glycol</td>
<td>EG</td>
</tr>
<tr>
<td>1 volume part of glycol and 1 volume part of water</td>
<td>$1_g/1_w$</td>
</tr>
<tr>
<td>1 vol. part of glycol and 2 vol. part of water</td>
<td>$1_g/2_w$</td>
</tr>
<tr>
<td>2 vol. part of glycol and 1 vol. part of water</td>
<td>$2_g/1_w$</td>
</tr>
<tr>
<td>Pure water</td>
<td>water</td>
</tr>
</tbody>
</table>

**Table 2. The activation energy for different mixtures.**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Temperature range (K)</th>
<th>Activation energy (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>296–393</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>$2_g/1_w$</td>
<td>291–383</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>$1_g/1_w$</td>
<td>348–358</td>
<td>1.1 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>358–376</td>
<td>0.2 ± 0.1</td>
</tr>
<tr>
<td>$1_g/2_w$</td>
<td>294–333</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>333–353</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>353–372</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>Water</td>
<td>296–340</td>
<td>0.6 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>340–370</td>
<td>0.2 ± 0.1</td>
</tr>
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</table>


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