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Dielectric Constant

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Abstract

The aim of the experiment is to measure the **temperature dependent dielectric constant** for two different dielectric media:

- **4-Chlorotoluene**
- **p-Xylene**

Contents

1 Theory

An electric field in a dielectric medium interacts with the charges present in it inducing a polarization. There are mainly two different mechanisms throughout which polarization can be induced.
Deformation Polarization: in every molecule the charge distribution is deformed by the electric field producing a dipole moment aligned to the electric field.
Orientation Polarization: this is only present in the case of molecules with a permanent dipole moment. The molecular dipoles tend to align to the external electric field.
Following Langevin-Debye theory (i.e. J. D. Jackson "Classical Electrodynamics" §§4.6) it is possible to describe how the total molecular polarizability depends on deformation polarizability, molecular permanent dipole moment and temperature.

$$\gamma_{mol} = \gamma_i + \frac{1}{3\varepsilon_0}\frac{p_0^2}{KT} \tag{1}$$

What is measured in the experiment is not the **molecular polarizablity** but the **dielectric constant**. Theory (i.e. J. D. Jackson "Classical Electrodynamics" §§4.3 and 4.5) allows to link the property of a single molecule (molecular polarizablity) to a property of the media (dielectric constant):

$$\gamma_{mol} = \frac{3}{N}\left(\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right) \tag{2}$$

The final result of this theory is equation 2, also called **Clausius-Mossotti** equation.

2 Experiment

Measure all the dimensions of the capacitor with a ruler and try to calculate C_0 from geometrical arguments.
Measure the capacity C_0 and compare it with the value calculated before. Fill the capacitor with p-Xylene and measure the capacity C for different (something about ten) temperatures between room temperature and the maximum you can get with your equipment ($\approx 70\ °C$). Be careful, dip the thermocouple head in the liquid and wait until the temperature is stable. Wash the capacitor carefully with ethanol and repeat the same for 4-Chlorotoluene. Don't forget to take into account that the coaxial cable itself is a capacitor!

3 Data Analysis

Knowing that $\varepsilon_r = C/C_0$ and using the Clausius-Mossotti equation, you arrive to obtain γ_{mol}. From equation 1 you expect a behaviour $\gamma_{mol} = a + b/T$ for molecules with a permanent dipole and $\gamma_{mol} = a$ for the others. Plot your value of γ_{mol} vs

$1/T$ and find out which of the two chemicals is made of molecules with permanent dipole moment. Fit the data obtained for 4-Chlorotoluene and for p-Xylene with the proper function in order to find out the value of γ_i. In the case of the permanent dipole molecule extrapolate the value of the permanent dipole moment for a single molecule from the fit.

4 Data

You can use some of the following data for your calculations:

	density (g/ml)	molecular weight (g/mol)	density ($molecule/m^3$)	ε_r (20 $°C$)
4-Chlorotoluene	1.068	126.59	$5.08 \cdot 10^{27}$	6.08
p-Xylene	0.861	106.17	$4.88 \cdot 10^{27}$	2.27

Moreover the dipole moment for a 4-chlorotoluene molecule is:
$p_0 = 2.21$ debye $= 7.36 \cdot 10^{-30}\ Cm$