University of Basel
Department of Physics

Paul Mosser, 3.04
paul.mosser@unibas.ch

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 (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!

2.1 Chemical Waste Disposal

Do not put any of the chemicals in the drain. The chemicals are hazardous to the environment and need to be disposed of in the containers prepared for them. Make sure that you put all chemicals used in the organic waste container.

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 $= 7.36 \cdot 10^{-30}\ Cm$