Dielectric Constant

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The aim of the experiment is to measure the **dielectric constant** in function of **temperature** for two different dielectric media
- a molecule with permanent dipole: **4-chlorotoluene**
- a non polar molecule: **p-Xylene**

Theory

An electric field in a dielectric medium is interacting with the charges present in it inducing its 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 molecule 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) is possible to describes how the total molecular polarizability depends on deformation polarizability, molecular permanent dipole moment and temperature

$$\gamma_{mol} = \gamma_i + \frac{1}{3\epsilon_0}\frac{p_0^2}{KT} \tag{1}$$

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)

$$\gamma_{mol} = \frac{3}{N}\left(\frac{\epsilon_r/\epsilon_0 - 1}{\epsilon_r/\epsilon_0 + 2}\right) \tag{2}$$

Final result of this theory is equation 2 also called Clausius-Mossotti equation.

Experiment

Measure with a ruler all the dimension of the capacitor and from geometrical arguments try to calculate C_0.
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 (about $70°C$). Be careful, dip the thermocouple head in the liquid and wait until temperature gets stable.
Wash carefully the capacitor with ethanol and repeat the same for 4-chlorotoluene.
Don't forget to take in account that the coaxial cable is itself a capacitor !

Data Analysis

Knowing that $\epsilon = C/C_0$ and using 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 one 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 from the fit extrapolate the value of the permanent dipole moment for a single molecule.

Data

To carry on your calculation you can use some of the following data:

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

Moreover the dipole moment for a 4-chlorotoluene molecule is
$p_0 = 2.21\, debye = 7.36\, 10^{-30}\, C\, m$