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Dielectric Constant Determination for Aqueous Solutions of Alcohol

Dielectric constant is a measure of a material's ability to store electrical energy when placed in an electrical field. It is also referred to as relative permittivity; it is typically denoted as ε_r; and it is defined as:

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

where ε is the permittivity of the material, and ε_0 is the permittivity of vacuum. Relative permittivity is the factor by which the electrical field between two point charges is reduced by the material relative to vacuum. It can also be expressed as the ratio of the capacitance of a capacitor using the material as a dielectric, C_x, compared to the capacitance of a similar capacitor using vacuum as a dielectric, C_0:

$$\varepsilon_r = \frac{C_x}{C_0}$$

While the dielectric constants for most pure liquids are easy to find, they may vary depending on the impurities present in the liquids or if the liquids are mixed with other liquids. Since there is no universal way to calculate the dielectric constant of a mixture, the best way to determine the dielectric constant is to measure the dielectric constant of the liquid mixture directly. This is especially useful for Zeta potential measurements where the liquid used to keep particles in suspension may be comprised of several different liquids.

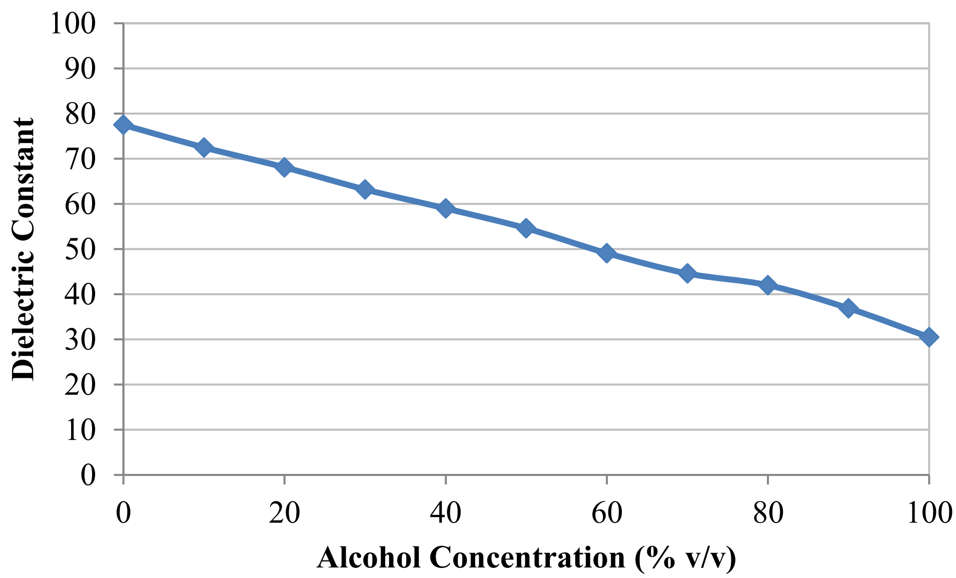

Figure 1. Dielectric constants of aqueous solutions with different concentrations of alcohol.

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The Brookhaven BI-870 Dielectric Constant Meter, equipped in Ebatco's Nano Analytical and Testing (NAT) Lab, is capable of measuring the dielectric constants of liquids. The BI-870 utilizes two concentric stainless-steel cylinders as a probe. The instrument generates a 10 kHz very low distortion sine wave of electrical signal at the outer cylinder and measures the conductive and capacitive currents between the two cylinders at the inner cylinder. By measuring the currents generated by this stable voltage source and knowing precisely the probe parameters, the dielectric constant of a liquid can be readily measured.

Figure 1 and Table 1 show the measured dielectric constants of aqueous solutions with various concentrations of denatured alcohol at room temperature. The results show a relatively linear relationship for the dielectric constants of water and denatured alcohol solutions with their alcohol concentrations.

In this instance, the dielectric constants for the solutions containing other alcohol concentrations can be approximated using the linear relationship. However, for many other mixtures, especially for more complex mixtures, this may not be the case. As the instrument manufacturer has stated "Although it is very tempting to try to apply simple mixing rules to approximate a new dielectric constant, there is no simple equation that will adequately characterize the interaction of fluids to calculate dielectric constants of mixed liquids. Thus direct measurement is the only recourse." When the dielectric constants of liquids are needed for their intended uses, measurements should and can be made in order to obtain precise and accurate values.

Table 1 Dielectric Constants of Aquesous Solutions with Various Concentrations of Alcohol

Alcohol Concentration (% v/v)	**Dielectric Constant**
0	77.5
10	72.5
20	68.1
30	63.2
40	59.0
50	54.6
60	49.1
70	44.6
80	42.0
90	36.9
100	30.5