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Viscoelectric Effect in n-Decanol and Amyl Acetate

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Summary Measurement of the bulk viscosity of n-decanol and amyl acetate in the presence of a static electric field without transverse currents shows that the viscosity decreases in proportion to the square of the field, and that the effect varies with temperature.

EARLY measurements have shown that a high intensity transverse electric field leads to a measurable increase in the viscosity of polar liquids, but the apparatus used for these measurements allowed the presence of a small transverse current.[1] Since measurement of the velocity of liquid flow on the basis of the volume between two points in the apparatus does not give information about the uniformity of flow, which can vary over a wide range (see below), we have designed a viscometer which allows the uniformity of flow to be monitored in this type of measurement, and avoids transverse currents. In our viscometer the metallic plates are covered with a sheet of Mylar of constant thickness which prevents metal–liquid contact, constant-pressure flow is maintained throughout the experiment, and the flow velocity is calculated from the number of drops emerging from the viscometer in a given time.

TABLE 1. Variation of viscosity with applied electrical field for n-decanol.

$V_{app.}$/V	E/V cm^{-1}[a]	t^*/s	$10^2(\Delta\eta/\eta)$
T = 293 K[b]			
2000	21·871	74·76	0·862
2500	27·339	74·31	1·460
3000	32·807	73·82	2·110
3500	38·275	73·11	3·050
4000	43·743	72·36	4·040
4800	52·494	71·14	5·660
T = 303 K[c]			
2000	23·861	48·06	0·764
2500	29·797	47·84	1·220
3000	35·758	47·63	1·650
3500	41·718	47·23	2·480
4000	47·679	46·88	3·200
4800	57·209	46·19	4·630
T = 313 K[d]			
2000	26·230	34·07	0·467
2500	32·791	33·98	0·730
3000	39·351	33·86	1·080
3500	45·907	33·74	1·430
4000	52·467	33·60	1·840
4800	62·960	33·33	2·630

[a] $E = V_{app.}/\epsilon d$; d is the distance between the plates in cm and values of the dielectric constant ϵ were kindly provided by H. G. Barbenza and N. Lopez. [b] $\epsilon = 8·12$, $t = 75·41$ s, $N = 5$. [c] $\epsilon = 7·45$, $t = 48·43$ s, $N = 5$. [d] $\epsilon = 6·77$, $t = 34·23$ s, $N = 5$.

Table 1 gives results for n-decanol at 293, 303, and 313 K, and Table 2 results for amyl acetate at 303 K. Values are averages of ten runs at 5 time intervals each. The accuracy in time measurement for each average is ± 0·02 s and the time intervals without applied electric fields are all constant in the range ± 0·02 s, showing that the liquid was flowing at constant speed during the experiments. The presence of field gradients in the direction of the flow is ruled out because measurements taken with the direction of flow reversed gives the same results as those in Table 1 and 2. The weight of liquid collected for each run shows that the weight of each drop remains constant (with or without applied field), and this constancy in the weight of each drop is an indication that the temperature of the liquid sheet remains constant during the whole experiment. At 303 K, the average weight of the n-decanol drops was 22·0 ± 0·1 mg and the amyl acetate 20·0 ± 0·1 mg. Measurements in polar liquids (alcohols, water, and amyl acetate) with a viscometer of the Andrade–Dodd type, giving currents of

Table 2. Variation of viscosity with applied electric field for amyl acetate at 303 K.[a]

$V_{\text{app.}}$/V	E/V cm^{-1}	t^*/s	$10^2(\Delta\eta/\eta)$
2000	42·328	17·56	1·840
2500	52·910	17·35	3·020
3000	63·492	17·10	4·420
3500	74·074	16·82	5·980
4000	84·656	16·58	7·320

[a] $\epsilon = 4{\cdot}2$ (International Critical Tables); $t = 17{\cdot}89$ s; $N = 5$.

ca. 0·04—7·50 mA showed a strong fluctuation between the time interval for each pair of drops, and also a variation in the weight of each drop. Electrolytic attack on the plates was also apparent in this type of apparatus.

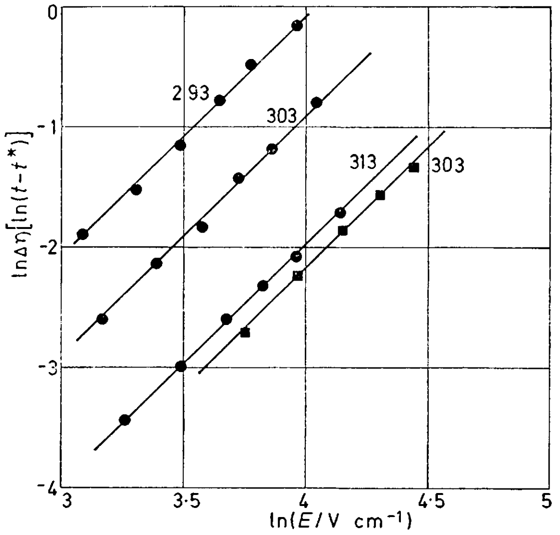

Figure. Variation of ln($\Delta\eta$) [ln ($t - t^*$)] as a function of ln-(E) for $KP\rho/NW = 1$: ●, n-decanol; ■, amyl acetate.

In order to use the relationship $\eta = KP/Q$ between the viscosity η, the viscometer constant K, the pressure P, and the flow rate Q, Q must be expressed as a function of the number of drops per unit time. Since the drop weight W remains constant under all conditions (at constant temperature), the viscosity will be given by equation (1) and the change in viscosity $\Delta\eta$ on application of an electric field by equation (2), where t^* and t, respectively, are the elapsed times with and without an applied electric field, N is the number of intervals for ($N + 1$) drops, and ρ is the density.

$$\eta = KP\rho t/NW \qquad (1)$$

$$\Delta\eta = \eta - \eta^* = (KP\rho t/NW)(t - t^*) \qquad (2)$$

Since $KP\rho t/NW$ is constant, we arbitrarily assign it a value of unity, and the way in which $\Delta\eta$ varies with applied electric field gradient E may be illustrated simply by plotting $\ln(t - t^*)$ ($\equiv \ln\Delta\eta$) against $\ln E$. The slopes of the plots for n-decanol and amyl acetate (Figure) show that η^*/η depends on the square of the electric field gradient according to equation (3), where γ is a constant.

$$\eta^* = \eta(1 - \gamma E^2) \qquad (3)$$

We feel that the drastic difference between our results and those reported by Andrade *et al.*[1] are due to the effect of transverse currents on their apparatus which we have not yet been able to analyze.

We thank Ing. H. Gellon for the design and assembly of the electronic drop counter.

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[1] E. N. da C. Andrade and C. Dodd, *Proc. Roy. Soc.*, 1946, *A*, **187**, 296; 1951, *A*, **204**, 449; E. N. da C. Andrade and J. Hart, *ibid.* 1954, *A*, **222**, 463.