Studies on the Oiliness of Liquids. VII. Measurements of the Static Friction Coefficients of Esters, Ketones and Glycerine.

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The measurements of the static friction of glass surfaces, when various organic liquids are present as lubricant, have already been reported in the previous papers.(1) The liquids tested contain polar compounds as well as non-polar ones. The former consists, mostly, of alcohol and normal acids, which have the polar group at one end of their molecules. It is interesting to know whether the shape of the molecule has the effect on the lubricating activity or not. In the present experiments, therefore, esters and ketones have been tested as lubricating liquids. These compounds have the polar group at the middle part of the molecule. Glycerine was also tested, which has three polar groups in a relatively small molecule. We have reported in the preceding papers, that the friction coefficients of water(2) and methyl alcohol(3) are 0.75 and 0.62 respectively. These

(1) J. Sameshima, M. Kidokoro and H. Akamatu, this Bulletin, **11** (1936), 659 ; H. Akamatu and J. Sameshima, *ibid.*, **11** (1936), 791 ; J. Sameshima and Y. Tsubuku, *ibid.*, **12** (1937), 127 ; H. Akamatu, *ibid.*, **13** (1938), 127.
(2) H. Akamatu, *ibid.*, **13** (1938), 131.
(3) J. Sameshima, M. Kidokoro and H. Akamatu, *ibid.*, **11** (1936), 663.

data have been revised and found that they are somewhat too low. The results will be described in the following lines.

The experiment was pursued by the balance method. The friction surfaces consisted of a flat glass and a glass with a spherical surface. They were cleaned sufficiently prior to each experiment by the same method as described in the former paper. The purest samples available were used in the experiments. All esters and ketones were sufficiently dried with quick lime or anhydrous potassium carbonate and then distilled before the experiment. Glycerine was distilled six times in vacuum to expel the last trace of water contained in it. The measurements were conducted at room temperature without any special adjustment of temperature because the coefficient of friction is not seriously affected by the change of temperature. The results obtained are summarised in Table 1. Fig. 1 shows the relations between the friction coefficient and the number of carbon atoms in the molecule of the substance.

Table 1.

Lubricant	W	F	μ
Methyl acetate	21.55	18.52	0.86
	21.55	18.52	0.86
	23.85	20.90	0.88
	23.85	21.70	0.91
	27.00	22.88	0.85
	27.00	22.18	0.82
	29.30	26.95	0.92
			0.87
Ethyl acetate	21.55	17.50	0.81
	25.40	21.12	0.83
	27.00	21.60	0.80
	29.30	23.70	0.81
	29.40	24.18	0.82
			0.81
n-Propyl acetate	14.50	12.00	0.83
	17.00	13.18	0.78
	19.30	15.55	0.81
	19.30	15.15	0.79
	27.00	21.30	0.79
	29.30	24.25	0.83
			0.81
n-Butyl acetate	19.40	15.43	0.80
	23.85	19.08	0.80
	27.00	20.64	0.77
	29.30	22.40	0.77
	31.70	23.99	0.76
	35.40	26.50	0.75
	37.70	31.40	0.83
			0.78
n-Amyl acetate	21.55	15.60	0.73
	23.55	17.30	0.74
	23.85	17.70	0.74
	27.70	19.48	0.72
	29.30	22.38	0.76
	29.30	21.80	0.74
	37.70	27.88	0.75
			0.74
n-Octyl acetate	21.55	15.54	0.72
	23.85	17.05	0.72
	27.00	19.33	0.72
	29.30	21.64	0.74
	35.40	25.78	0.72
	37.70	28.90	0.77
			0.73
Ethyl propionate	14.10	11.90	0.85
	15.70	13.20	0.84
	19.30	15.05	0.78
	23.35	17.70	0.76
	29.30	23.10	0.79
	30.05	23.80	0.79
	33.35	26.10	0.79
			0.80
Ethyl butylate	15.00	12.20	0.81
	16.60	13.10	0.79
	23.85	19.50	0.82
	27.00	21.60	0.80
	27.90	22.02	0.79
	29.30	23.10	0.79
	31.55	24.98	0.79
			0.80
Acetone	14.35	12.54	0.88
	17.30	14.80	0.86
	18.35	14.89	0.81
	21.05	18.25	0.87
	27.02	23.20	0.86
			0.86

Table 1.—(*Concluded*)

Lubricant	W	F	μ
Methyl ethyl ketone	21.30	17.65	0.83
	21.30	17.35	0.81
	24.30	19.20	0.79
	26.30	22.40	0.85
	26.30	21.70	0.83
	29.30	25.00	0.85
			0.83
Diethyl ketone	17.00	13.85	0.82
	19.30	15.95	0.83
	19.30	15.96	0.83
	23.35	20.00	0.86
	27.00	23.12	0.86
	29.30	25.95	0.81
			0.84
Acetophenone	19.30	13.90	0.72
	27.00	19.15	0.71
	29.30	20.82	0.71
	29.30	22.18	0.76
	29.30	21.25	0.73
	31.05	22.40	0.72
	33.35	25.05	0.75
	33.85	24.01	0.71
			0.73

Lubricant	W	F	μ
Glycerine	25.70	21.43	0.84
	48.40	42.30	0.88
			0.86
Water	16.05	14.35	0.89
	19.45	17.83	0.92
	20.75	19.20	0.93
	20.80	19.50	0.94
	22.70	19.65	0.87
	24.50	21.30	0.87
	26.15	23.60	0.90
			0.90
Methyl alcohol	17.10	13.79	0.81
	20.30	16.45	0.81
	20.85	15.98	0.77
	21.50	15.86	0.74
	23.70	18.47	0.78
	24.15	19.45	0.81
			0.79

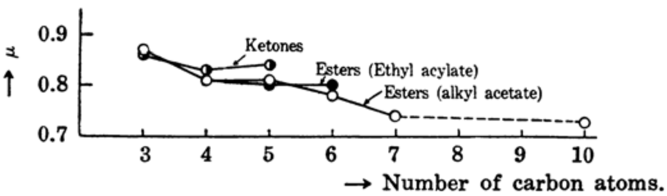

Fig. 1.

We know from Table 1, that all these substances—esters, ketones, and glycerine—give relatively high friction coefficients. So it may be concluded from these results, that substances which have the polar group at the middle part of the molecule do not serve as good lubricants. The polar molecule attaches to the friction surface with its polar group and presenting non-polar chain to the liquid interface, forming a monomolecularly orientated layer.(4) A substance serve as a better lubricant when molecules take regular arrangement on the sliding surface than they take irregular arrangement.(5) The esters and ketones have the polar group at the middle part of the molecule, with which they may anchor on the surface. It is recognisable from this fact that they take regular arrangement more difficultly than the molecules having polar group at the end of the molecule. This may be the reason of high friction coefficients of esters and ketones.

(4) Hardy and Doubleday, *Proc. Roy. Soc.* (London), A, **104** (1923), 25; Akamatu, this Bulletin, **13** (1938), 127.

(5) H. Akamatu and J. Sameshima, *ibid.*, **11** (1936), 793.

As already reported in the preceding papers, the lower homologous are poorer lubricants than the higher homologous in the aliphatic alcohol series.[6] The analogous fact is also observed in the ester series, although they give always higher friction coefficients than alcohols. However, the effect of chain length of alkyl group in the ester is more predominated than the effect of that of acyl group.

The high static friction coefficient of glycerine is also ascribable to its molecular structure. When glycerine is placed on the sliding surface, it attaches to the surface with its three polar groups and the molecule can hardly be inclined according to the anchoring with these groups. Moreover, no flexibility can considered of its molecule for the shortness of its chain. The fricition coefficient of water was determined to be 0.9. It is the highest friction coefficient we ever obtained on the glass surface in the pressence of lubricant. Hardy and Doubleday stated that water is neutral to the surfaces of glass or steel in that it neither lowers nor raises the friction.[7] This fact may be probably ascribable to the very short chain of the molecule.

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Summary.

(1) The static friction coefficients have been measured when esters, ketones and glycerine are placed on the glass surface as lubricants.

(2) The friction coefficients of these liquids are very high.

(3) Some considerations have been made on the high friction coefficients of these liquids.

(4) The friction coefficients of water and methyl alcohol have been revised.

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(6) J. Sameshima, M. Kidokoro and H. Akamatu, *ibid.*, **11** (1936), 659; J. Sameshima and Y. Tsubuku, *ibid.*, **12** (1937), 127.

(7) Hardy and Doubleday, *Proc. Roy. Soc.* (London), A, **104** (1923), 34.