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79	2-Methylpropionic acid(isobutyric acid)	276-382	-	-	-	-	18.99	0.60
80	(di)Methyl sulfide	273-309	-	-	32.27	-	26.36	0.06
81	Nonadecane	308-343	6.59	3.95	60.60	2.12	-	0.08
82	Nonane	273-373	0.78	1.01	29.53	0.98	10.07	0.34
83	Octadecane	303-373	2.00	3.24	67.74	1.93	4.29	1.10
84	Octane	273-395	2.89	2.21	15.86	2.73	6.40	0.38
85	trans-2-Octene	293-373	3.65	4.95	17.20	-	8.56	0.34
86	Oxirane (ethyleneoxide)	223-283	-	-	-	-	17.79	0.61
87	Pentachloroethane	273-353	12.88	6.35	45.24	9.29	-	0.92
88	n-Pentadecane	293-373	2.59	2.43	52.57	6.16	3.70	1.20
89	n-Pentane	273-323	3.45		4.26	14.08	2.72	0.44
90	2-Pentanone	273-372	24.55	3.05	4.58	99.84	1.60	0.18
91	3-Pentanone	273-372	33.85	3.15	7.30	-	5.81	0.25
92	1-Pentene	183-273	6.09	4.36	8.03	1.64	33.69	0.57
93	2-Pentene	293-308	3.59	6.93	3.22	3.91	24.65	0.26
94	2-Picoline	273-353	-	-	-	-	5.30	0.39
95	propionaldehyde	288-321	1.15	5.82	33.52	4.23	26.36	0.19
96	Propionic acid	277-374	27.57	4.15	14.69	-	11.33	0.45
97	Propionitrile	293-370	-	-	2.89	37.81	5.63	0.22
98	Propyl acetate	273-370	9.46	0.96	24.20	9.90	13.50	0.15
99	Propyl ether	273-361	4.39	11.27	23.30	1.29	1.25	0.21
100	n-Propyl formate	273-350	2.97	7.65	20.88	-	10.23	0.14
101	Pyridine	273-353	-	38.04	34.94	4.29	8.87	0.71
102	Styrene	273-413	6.96	16.21	12.34	-	28.78	1.35
103	n-Tetradecane	283-373	3.56	3.88	46.90	6.93	10.61	2.13
104	n-Tridecane	273-373	5.16	2.03	45.00	9.80	13.44	1.69
105	Trifluoroacetic acid	292-338	-	-	-	-	-	0.21
106	1,1,2-Trifluoro 1,2,2trichloroethane	293-318	-	-	42.50	-	34.74	0.08
107	n-Undecane	273-373	3.28	1.57	37.20	1.75	13.80	1.15
108	m-Xylene	273-373	0.82	4.62	4.56	2.78	22.86	0.16
109	o-Xylene	273-373	4.15	7.66	2.44	12.25	7.27	0.50
110	p-Xylene	281-384	1.18	4.03	40.31	3.15	16.86	0.78
111	Decene	293-393	8.20	3.91	40.97	0.72	4.72	0.39
	Overall AAD %		12.79	8.86	23.36	13.95	11.79	0.58

(-) Model-parameters not available.

45	Ethylformate	273-325	5.71	1.90	21.15	-	5.42	0.09
46	Ethylpropionate	273-363	18.96	6.49	13.81	9.61	8.44	0.14
47	Fluorobenzene	273-354	3.32	21.84	1.59	-	1.15	0.8
48	2-Furaldehyde (Furfural)	273-373	33.50	-	43.62	-	5.89	1.64
49	n-Heptadecane	303-413	11.52	2.14	54.33	1.01	1.28	1.43
50	n-Heptane	263-373	0.55	0.60	17.49	0.90	4.14	0.19
51	2-Heptanone	293-353	66.64	18.74	27.11	15.67	-	4.36
52	1-Heptene	273-303	8.84	4.80	10.67	27.41	15.92	0.59
53	n-Hexadecane	293-393	7.10	1.82	50.55	3.47	1.59	1.51
54	n-Hexane	273-333	6.77	4.61	7.76	4.79	1.48	0.21
55	Hexanenitrile	290-391	-	-	35.34	25.15	8.80	0.49
56	Indane	273-393	37.92	39.82	37.92	-	5.31	2.48
57	Iodobenzene	277-380	16.87	14.19	1.85	-	30.55	1.33
58	Ethyl iodide	273-342	12.23	0.62	8.76	-	19.79	0.16
59	Methyl iodide	273-313	-	-	-	-	-	0.03
60	Isobutylacetate	293-393	7.81	5.68	28.30	23.50	14.71	0.58
61	Isoheptane	273-361	3.36	4.30	18.71	0.57	1.44	0.41
62	1-Methoxypropane	273-308	1.96	9.61	-	-	9.72	0.09
63	Chlorobenzene	273-353	-	-	-	-	17.95	0.84
64	Methylacetate	273-327	1.10	3.46	12.22	14.03	0.73	0.14
65	2-Methyl-1,3- Butadiene	273-303	13.58	6.72	6.22	-	29.82	0.03
66	2-Methylbutane	273-299	9.74	0.38	11.25	0.64	3.68	0.06
67	2-Methyl-2-Butene	273-306	4.78	5.27	8.7	-	15.71	0.07
68	Methyl butyrate	273-371	11.04	0.78	19.58	23.59	8.70	0.13
69	Methylcyclohexane	285-373	14.46	4.24	41.21	1.91	22.78	0.48
70	Methylcyclopentane	248-323	19.18	22.65	43.13	29.07	19.49	0.31
71	Methyl ethyl ketone	273-349	11.72	6.68	11.37	36.05	1.01	0.06
72	Methyl formate	273-302	17.75	4.54	29.22	-	0.44	0.11
73	3-Methyl hexane	288-303	-	-	-	-	7.27	0.77
74	Methyl isobutyrate	273-362	16.56	2.15	18.49	-	9.48	0.73
75	2-Methyl pentane	273-328	4.04	4.63	19.39	2.47	1.34	0.17
76	3-Methyl pentane	273-303	8.82	10.91	18.36	5.53	1.71	0.27
77	4-Methyl- 2pentanone	293-318	37.61	1.80	22.83	-	4.73	0.37
78	Methyl propionate	273-349	9.43	3.41	11.05	10.42	3.21	0.17

10	Biphenyl	373-498	27.56	0.66	1.59	-	16.86	0.25
11	Bromoethane	273-309	27.31	3.67	20.57	10.62	36.79	0.04
12	Bromobenzene	273-373	9.89	6.88	2.23	59.89	22.29	1.31
13	Butane	273-323	20.46	5.56	3.03	4.17	2.91	0.56
14	1,3-Butadiene	253-333	18.87	18.50	24.29	-	28.27	0.9
15	Butyl acetate	273-373	13.41	4.74	29.31	5.99	12.22	0.51
16	Butyl benzene	283-353	5.89	3.72	36.18	2.10	8.20	0.50
17	Butyl ether	273-373	7.34	29.11	40.23	1.96	4.44	0.40
18	Butyraldehyde	291-348	4.04	11.20	34.21	9.49	17.01	0.05
19	n-Butyric acid	276-374	24.79	3.84	26.20	1.67	12.89	0.93
20	Butyronitrile	288-391	35.71	-	28.69	-	13.11	0.26
21	Carbontetrachloride	293-393	15.90	4.18	10.02	2.38	16.34	0.43
22	Chloroform	252-353	32.18	5.88	7.78	1.27	7.08	0.08
23	1-Chloropropane	273-318	17.51	3.09	20.64	3.65	5.11	0.27
24	Cumene	273-313	0.32	0.32	32.40	-	8.33	0.29
25	Cyclohexane	293-353	41.10	32.10	24.71	2.13	-	0.47
26	Cyclohexanone	289-426	26.24	48.33	42.96	26.17	-	1.10
27	Cyclopentane	273-313	31.76	31.46	31.51	0.51	16.73	0.15
28	Cis-Decaline	293-393	30.59	42.32	56.94	-	-	1.33
29	Decane	273-373	1.43	2.89	30.10	2.55	11.30	0.76
30	1,2-Dichlorobenzene	296-397	10.54	15.87	10.60	-	30.04	0.34
31	Dichloromethane	277-374	5.49	11.28	29.81	2.49	8.79	0.42
32	1,4-Difluorobenzene	293-333	23.2	28.87	42.42	-	-	0.97
33	N,N-Dimethylaniline	283-371	-	10.25	4.27	95.35	5.04	0.77
34	2,2-Dimethylbutane	273-303	5.93	3.23	28.56	26.04	24.06	0.45
35	N,N-Dimethyl-o-toluidine	345-458	-	-	-	-	1.18	0.27
36	Diphenylmethane	332-534	17.17	32.67	17.53	-	1.26	0.60
37	Dodecane	273-373	4.22	1.60	51.66	1.20	16.29	1.27
38	Eicosane	313-413	12.22	2.20	62.41	2.73	-	1.94
39	Diethylether	280-305	-	-	-	-	17.73	0.25
40	Phenyl ethyl ether	291-391	-	-	-	-	8.09	1.38
41	Ethyl acetate	273-347	10.03	5.48	9.30	8.61	1.25	0.23
42	Ethyl benzene	273-381	0.51	2.58	18.10	0.91	13.96	0.14
43	Ethyl butyrate	288-323	-	-	-	-	9.65	1.26
44	Ethylcyclohexane	273-313	5.89	1.42	41.19	2.34	22.83	0.18

89	n-Pentane	5	273-323	6341	-170.322	0.44	0.0049
90	2-Pentanone	12	273-372	8955	-173.718	0.18	0.0021
91	3-Pentanone	12	273-372	8728	-173.579	0.25	0.0029
92	1-Pentene	19	183-273	6398	-172.077	0.57	0.0072
93	2-Pentene	4	293-308	9054	-180.759	0.26	0.0029
94	2-Picoline	9	273-353	10369	-175.796	0.39	0.0048
95	propionaldehyde	7	288-321	8606	-177.122	0.19	0.0024
96	Propionic acid	9	277-374	10856	-174.556	0.45	0.0059
97	Propionitrile	8	293-370	8494	-171.921	0.22	0.0029
98	Propyl acetate	11	273-370	9895	-175.965	0.15	0.0017
99	Propyl ether	12	273-361	9015	-175.419	0.21	0.0026
100	n-Propyl formate	12	273-350	9241	-175.133	0.14	0.0017
101	Pyridine	9	273-353	11477	-178.441	0.71	0.0091
102	Styrene	15	273-413	10811	-177.713	1.35	0.0168
103	n-Tetradecane	10	283-373	14895	-179.943	2.13	0.0254
104	n-Tridecane	11	273-373	14146	-179.651	1.69	0.0197
105	Trifluoroaceticacid	6	292-338	11444	-178.450	0.21	0.0029
106	1,1,2-Trifluoro-1,2,2-trichloroethane	4	293-318	9707	-176.820	0.08	0.0009
107	n-Undecane	12	273-373	12249	-177.169	1.15	0.0140
108	m-Xylene	11	273-373	9276	-173.723	0.16	0.0022
109	o-Xylene	9	273-373	10469	-175.721	0.50	0.0060
110	p-Xylene	10	281-384	9616	-174.490	0.78	0.0131
111	Decene	8	293-393	10798	-175.353	0.39	0.0044
	Overall	1025				0.58	0.0066

Table (3) Comparison of the calculated (AAD%) in viscosities by using the new and other models.

No.	Name	T Range	Orrick & Erbar	Vanvelzen et al.	Sridhar & Przez.	Cao et al.	New Eq. (12)	New Eq. (8)
1	Acetaldehyde	273-294	2.81	7.47	13.51	26.79	8.48	0.11
2	Acetic acid	298-385	3.16	24.59	1.17	32.93	36.65	0.30
3	Acetone	281-327	1.73	0.82	1.05	45.23	2.71	0.19
4	Acetonitrile	289-354	-	-	28.09	37.39	10.73	0.09
5	Acetophenone	298-474	2.71	7.21	0.93	-	5.38	1.34
6	Allyl chloride	273-315	15.47	0.79	-	-	19.25	0.06
7	Anisole	287-387	22.43	6.72	12.17	83.54	3.52	0.14
8	Benzene	280-348	34.88	30.37	8.66	1.13	10.53	0.42
9	Benzonitrile	273-373	-	-	11.02	-	9.72	1.59

54	n-Hexane	7	273-333	7811	-172.934	0.21	0.0025
55	Hexanenitrile	6	290-391	11359	-175.912	0.49	0.0056
56	Indane	13	273-393	12250	-177.373	2.48	0.0296
57	Iodobenzene	11	277-380	11131	-175.216	1.33	0.0153
58	Ethyl iodide	12	273-342	7758	-172.217	0.16	0.0017
59	Methyl iodide	8	273-313	7201	-173.300	0.03	0.0003
60	Isobutylacetate	11	293-393	11224	-178.607	0.58	0.0066
61	Isoheptane	12	273-361	8457	-173.801	0.41	0.0046
62	1-Methoxypropane	8	273-308	7169	-173.338	0.09	0.0010
63	Chlorobenzene	7	273-353	9597	-173.911	0.84	0.0101
64	Methylacetate	11	273-327	8170	-174.126	0.14	0.0021
65	2-Methyl-1,3-Butadiene	4	273-303	6703	-172.804	0.03	0.0004
66	2-Methylbutane	9	273-299	7006	-173.215	0.06	0.0008
67	2-Methyl-2-Butene	8	273-306	6487	-171.814	0.07	0.0008
68	Methyl butyrate	11	273-371	9714	-175.632	0.13	0.0016
69	Methylcyclohexane	6	285-373	10500	-175.987	0.48	0.0054
70	Methylcyclopentane	16	248-323	8917	-173.828	0.31	0.0035
71	Methyl ethyl ketone	12	273-349	8631	-174.032	0.06	0.0008
72	Methyl formate	7	273-302	7392	-172.741	0.11	0.0013
73	3-Methyl hexane	3	288-303	8511	-174.357	0.77	0.0084
74	Methyl isobutyrate	11	273-362	9158	-174.621	0.73	0.0125
75	2-Methyl pentane	12	273-328	7772	-173.377	0.19	0.0022
76	3-Methyl pentane	6	273-303	7393	-171.652	0.27	0.0030
77	4-Methyl-2-pentanone	4	293-318	9713	-175.079	0.37	0.0041
78	Methyl propionate	11	273-349	8749	-174.454	0.17	0.0023
79	2-Methylpropionic acid(isobutyric acid)	9	276-382	11868	-175.791	0.60	0.0081
80	(di)Methyl sulfide	8	273-309	6858	-172.104	0.06	0.0007
81	Nonadecane	8	308-343	19557	-188.356	0.08	0.0010
82	Nonane	8	273-373	10499	-175.433	0.34	0.0039
83	Octadecane	8	303-373	17123	-181.856	1.10	0.0119
84	Octane	12	273-395	9581	-174.609	0.38	0.0046
85	trans-2-Octene	7	293-373	9344	-174.743	0.34	0.0037
86	Oxirane(ethylene oxide)	9	223-283	6456	-171.479	0.61	0.0074
87	Pentachloroethane	7	273-353	13986	-180.597	0.92	0.0099
88	n-Pentadecane	9	293-373	15274	-180.328	1.20	0.0139

19	n-Butyric acid	8	276-374	12643	-178.491	0.93	0.0114
20	Butyronitrile	11	288-391	9553	-173.347	0.26	0.0032
21	Carbontetrachloride	11	293-393	10987	-178.823	0.43	0.0056
22	Chloroform	8	252-353	7949	-172.673	0.08	0.0010
23	1-Chloropropane	10	273-318	7705	-173.439	0.27	0.0033
24	Cumene	5	273-313	10787	-176.805	0.29	0.0034
25	Cyclohexane	7	293-353	12353	-180.464	0.47	0.0056
26	Cyclohexanone	7	289-426	14260	-179.897	1.10	0.0125
27	Cyclopentane	5	273-313	8507	-173.829	0.15	0.0017
28	cis-Decaline	11	293-393	15190	-180.262	1.33	0.0165
29	Decane	8	273-373	11355	-176.339	0.76	0.0092
30	1,2-Dichlorobenzene	7	296-397	10873	-174.000	0.34	0.0040
31	Dichloromethane	8	277-374	7146	-171.706	0.42	0.0047
32	1,4-Difluorobenzene	5	293-333	12967	-182.815	0.97	0.0121
33	N,N-Dimethylaniline	10	283-371	12090	-176.860	0.77	0.0091
34	2,2-Dimethylbutane	5	273-303	8884	-175.556	0.45	0.0050
35	N,N-Dimethyl-o-toluidine	9	345-458	12159	-176.847	0.27	0.0040
36	Diphenylmethane	9	332-534	13974	-177.150	0.60	0.0068
37	Dodecane	8	273-373	13287	-178.525	1.27	0.0165
38	Eicosane	9	313-413	17257	-180.248	1.94	0.0218
39	Diethylether	13	280-305	7152	-173.880	0.25	0.0035
40	Phenyl ethyl ether	5	291-391	12563	-179.073	1.38	0.0154
41	Ethyl acetate	11	273-347	8940	-175.239	0.23	0.0036
42	Ethyl benzene	10	273-381	9578	-174.163	0.14	0.0018
43	Ethyl butyrate	5	288-323	10885	-178.061	1.26	0.0133
44	Ethylcyclohexane	5	273-313	10716	-175.434	0.18	0.0021
45	Ethylformate	11	273-325	8155	-173.685	0.09	0.0012
46	Ethylpropionate	11	273-363	9419	-175.136	0.14	0.0018
47	Fluorobenzene	11	273-354	8896	-173.918	0.80	0.0108
48	2-Furaldehyde(Furfural)	8	273-373	12861	-179.593	1.64	0.0196
49	n-Heptadecane	10	303-413	16039	-179.801	1.43	0.0166
50	n-Heptane	11	263-373	8324	-172.511	0.19	0.0023
51	2-Heptanone	8	293-353	15964	-194.877	4.36	0.0050
52	1-Heptene	7	273-303	7668	-171.757	0.59	0.0069
53	n-Hexadecane	10	293-393	15796	-180.456	1.51	0.0181

## Greek letters

$\nu$  frequency of movement of molecule

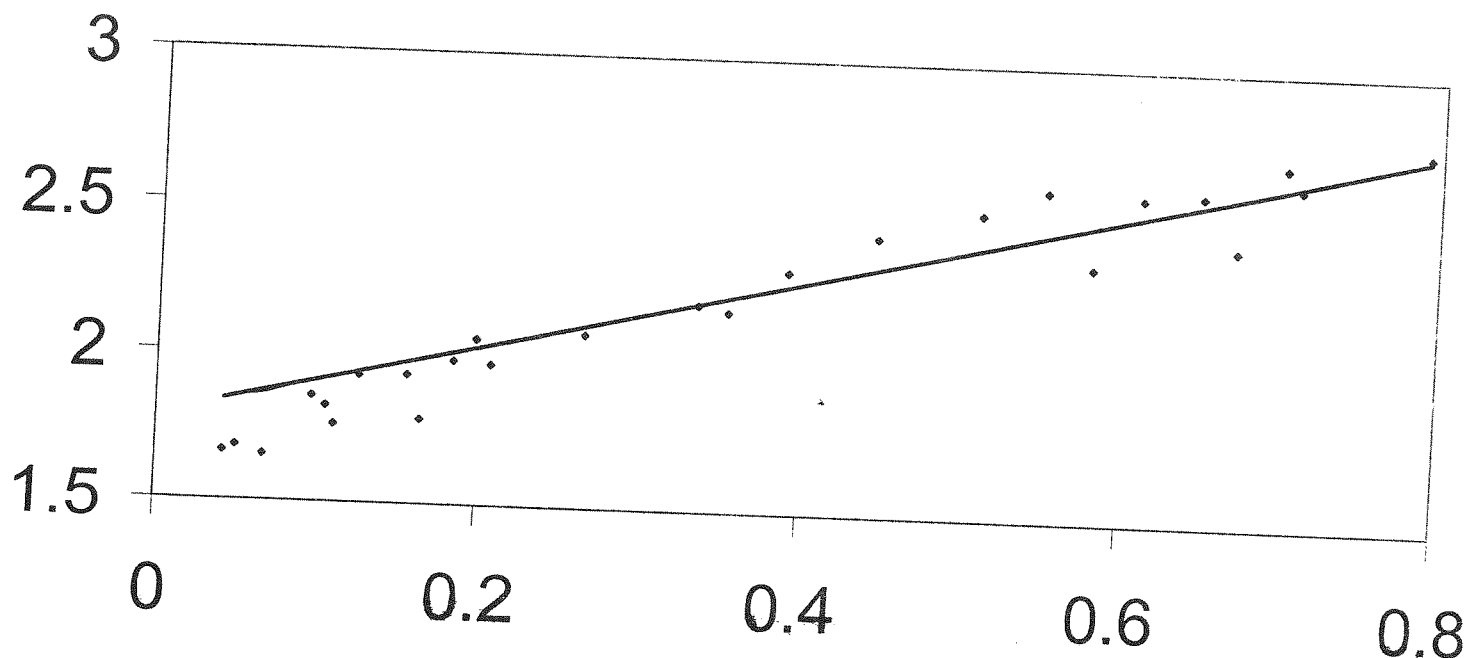


Figure (1) The variation of  $a^*$  versus  $\omega^2/T_{br}$

Table (1) a and b parameters for pure fluids according Equation (8).

NO.	Name	Data Point	T Range	a	b	AAD %	MRSD
1	Acetaldehyde	12	273-294	6711	-172.401	0.11	0.0012
2	Acetic acid	17	298-385	11718	-176.153	0.30	0.0033
3	Acetone	24	281-327	7581	-172.463	0.19	0.0024
4	Acetonitrile	7	289-354	8094	-171.123	0.09	0.0010
5	Acetophenone	7	298-474	12352	-176.126	1.34	0.0157
6	Allyl chloride	9	273-315	7567	-173.554	0.06	0.0008
7	Anisole	5	287-387	11887	-178.328	0.14	0.0018
8	Benzene	19	280-348	10914	-179.438	0.42	0.0050
9	Benzonitrile	9	273-373	11951	-176.584	1.59	0.0195
10	Biphenyl	6	373-498	14326	-178.928	0.25	0.0029
11	Bromoethane	8	273-309	7128	-173.583	0.04	0.0005
12	Bromobenzene	17	273-373	10113	-173.928	1.12	0.0140
13	Butane	5	273-323	6208	-172.320	0.56	0.0065
14	1,3-Butadiene	9	253-333	8317	-181.381	0.90	0.0103
15	Butyl acetate	8	273-373	10649	-176.752	0.51	0.0061
16	Butyl benzene	8	283-353	11322	-176.351	0.50	0.0064
17	Butyl ether	8	273-373	10451	-176.089	0.40	0.0049
18	Butyraldehyde	6	291-348	8734	-175.205	0.05	0.0006



$$b^* = -100(\omega^2 / T_{br}) - 149.16$$

(14)

The results of viscosity calculations by the equations proposed in this work, (equations 8 and 12) are compared with the best simple viscosity models. Some of these models are presented in Table(2)<sup>9,20-2</sup>

Table (2) Some of the best simple viscosity models.

Models	Proposed by:
$\ln \frac{\eta}{\rho M} = A + \frac{B}{T}$	Orrick and Erbar
$\ln \eta = D(T^{-1} - T_0^{-1})$	Vanvelzen, Cardozo and Langenkamp
$\eta = \frac{V_0}{F(V - V_0)}$	Sridhar and Przewdziecki
$\eta = \left(\frac{2\pi MRT}{V^2}\right)^{1/2} \exp\left(\frac{zqnu}{2RT}\right)$	Cao et al.

The results of calculations by using these models are reported in Table (3). This table indicates that the proposed equation in this work, equation (8), has the best predicting ability for viscosity calculation of pure fluids compared to other models, however, the obtained results by using equation (12) is acceptable.

In a subsequent paper it is intended to extend this equation for viscosity calculation of fluid mixtures.

### Notation

- $a, b$  activation energy parameters
- $a^*, b^*$  dimensionless activation energy parameters
- A, B, D, F and n viscosity model constants, in Table (1).
- k Boltzman constant
- $h$  Planck constant
- m molecular mass
- $M$  molar mass
- $N_0$  Avogadro's number
- $q$  parameter of the UNIFAC model, in Table (1).
- $u$  interaction potential energy
- $T_0^{-1}$  parameter in viscosity model, in Table (1).
- $V_0$  molar volume at the freezing point of the liquids, in Table (1).
- $Q_a$  partition function at activated state
- $Q$  partition function at initial state
- $R$  gas constant = 8.3143 (J/mol.K)
- $T$  Kelvin temperature
- $T_{br}$  reduced normal boiling point
- $V_f$  free volume
- $V$  molecule volume ( $m^3$ )
- $z$  parameter of the UNIFAC model, in Table (1).

$$E = a + bT \quad (7)$$

and equation (6) becomes:

$$\eta = \frac{1}{\sqrt{2/3}} (2\pi MRT)^{1/2} \exp\left(\frac{a+bT}{RT}\right) \quad (8)$$

where the constants  $a$  and  $b$  for each pure compound can be evaluated by fitting the experimental viscosity data in Equation (8).

## Results and Discussion

Equation (8) is used to correlate the viscosity experimental data of 111 pure fluids of varied properties at different temperatures. The molecular volume  $v$  of liquid is calculated by MMM equation of state<sup>25</sup>. The viscosity experimental data is extracted from Viswanath data book<sup>5</sup>.

The results of calculations are reported in Table (1). The error in the calculations are expressed as:

$$(\text{ERROR})\% = \frac{\eta_{cal} - \eta_{exp}}{\eta_{exp}} \times 100 \quad (9)$$

Also, the mean relative standard deviation (MRSD) is calculated as:

$$MRSD = \left( \frac{1}{N} \sum_1^m \left( \frac{\eta_{cal} - \eta_{exp}}{\eta_{exp}} \right)^2 \right)^{1/2} \quad (10)$$

where,  $N$  is the number of experimental data. The results of our calculations indicate that the overall average error is 0.58% and overall percentage MRSD is 0.69%.

The dimensionless parameters  $a^*$  and  $b^*$  are defined as:

$$a^* = \frac{a}{RT_c} \quad , \quad b^* = \frac{b}{R} \quad (11)$$

where,  $T_c$  is the critical temperature.

Therefore, the proposed viscosity equation, Equation (8), is rewritten as:

$$\eta = \frac{1}{\sqrt{2/3}} (2\pi MRT)^{1/2} \exp\left(\frac{a^*}{T_r} + b^*\right) \quad (12)$$

The calculations indicate that the dimensionless parameters,  $a^*$  and  $b^*$ , can be expressed in terms of compound's characteristics such as acentric factor ( $\omega$ ) and reduced boiling point temperature ( $T_{br} = T_b/T_c$ ) for the compounds listed in Table (1). Figure (1) shows the variation of  $a^*$  versus  $\omega^2/T_{br}$  for the compounds. According this figure  $a^*$  can be correlated in the following form:

$$a^* = 1.20(\omega^2/T_{br}) + 1.79 \quad (13)$$

and then further calculations indicate that:

data; nevertheless, the deviation between calculated and experimental values are, in general, greater than those obtained with the other types of models.

In this work, by proposing a simple temperature functionality for activation energy in the Eyring's absolute reaction rate theory for viscosities, the viscosity of pure compounds are calculated and the results are compared with those obtained with the other models.

## Theory

In the absolute reaction rate theory<sup>13</sup>, Eyring has shown that in a chemical reaction, an activation energy  $\varepsilon$ , is involved and the frequency of acquiring this activation energy can be expressed by:

$$\nu = \frac{kT}{h} \frac{Q_a}{Q} \exp\left(-\frac{\varepsilon}{kT}\right) \quad (1)$$

where,  $k$  and  $h$  are Boltzman and Planck constants respectively. The partition functions,  $Q$  and  $Q_a$  are respectively related to the initial and activated states of the reactants in the reaction. Since the flow of a liquid is a rate process, Eyring proposed that the theory of reaction rate can be applied to the viscosity of liquids. In this case, the ratio of  $Q/Q_a$  would be presented as:

$$\frac{Q}{Q_a} = \frac{(2\pi mkT)^{1/2}}{h} V_f^{1/3} \quad (2)$$

where  $m$  is the molecular mass,  $V_f$  is the free volume of liquid, and the other symbols are the same as used in Equation (1). On combining equations (1) and (2), we have:  
where,

$$1/\nu = (2\pi mkT)^{1/2} V_f^{1/3} \exp\left(\frac{\varepsilon}{kT}\right) \quad (3)$$

Since, the viscosity is considered as the resistance of a liquid to flow, it can be expressed as<sup>13</sup>:

$$\eta = (N/V)(1/\nu) \quad (4)$$

The proportionality constant  $(N/V)$ , accounts for the fact that there are  $N$  molecules in volume  $V$  of liquid.

In the absence of detailed information about intermolecular potential energy function,  $u$ , we use the following usual expression for the free volume<sup>19</sup>:

$$V_f = V \exp(u/kT) \quad (5)$$

Then, on combining equations (3), (4) and (5) for one mole of fluid, we have:

$$\eta = \frac{1}{\sqrt{2/3}} (2\pi MRT)^{1/2} \exp(E/RT) \quad (6)$$

In the above equation  $V$  is the molecule volume of liquid,  $M = N_0 m$ ,  $R = N_0 k$  and  $E = (\varepsilon + 1/3u) N_0$ .

$M$ ,  $R$ , and  $N_0$  are respectively, the molar mass, gas constant, and Avogadro number.

We assume that the activation energy of liquid can be expressed as:

# A New Two-Parameter Equation for Viscosity Calculations

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## Abstract

*In this work, the activation energy in the viscosity equation derived on the basis of Eyring's absolute rate theory is expressed in terms of a simple two-parameter linear function of temperature. The viscosity data of 111 pure components are used to evaluate the parameters of activation energy and then they are correlated in terms of each component characteristics, such as reduced boiling point and acentric factor. The results of viscosity calculations are compared with those of the other models and show a higher accuracy of the results obtained by the viscosity equation used in this work.*

## Keywords

*Viscosity, Eyring Theory, Evaluate reaction rate, Activation energy*

## Introduction

Knowledge of viscosity of pure liquids and respective mixtures is important for practical and theoretical purposes<sup>1-3</sup>. The viscosity of multicomponent liquid mixtures is an invaluable type of data for chemical engineer in design and optimization of industrial process. Furthermore, the simultaneous investigation of viscosity and volume effects on mixing can be a powerful tool for the characterization of the intermolecular interactions present in these mixtures.

Compilations of the viscosities of pure liquids at the different temperatures and pressures, as well as those of binary liquid mixtures through the whole composition range can be found in the literature.<sup>4-8</sup> Nevertheless, the situation changes in the case of multicomponent liquid mixtures.

Over the last years, numerous equations for liquid mixture viscosity have been proposed for implementation in computer prediction routines. The results, in general, are in poor agreement with experimental values, unless pure component and binary solution viscosity data are taken into account. A recent review, concerning viscosity modeling may be found in the work of Reid et al.<sup>9</sup>

Most of the methods available in the literature for calculations of liquid mixture viscosity are based on the principle of corresponding state,<sup>10-12</sup> the absolute rate theory of Eyring and co-workers, and more recently, molecular dynamic model<sup>13</sup>. The corresponding states techniques are restricted to a small number of systems and are not suitable for polar mixtures or mixtures exhibiting strong associations<sup>9</sup>. Careful inspection of the literature, particularly in the past decade, shows that use of viscosity model based on Eyring's absolute rate theory is a good approach for correlating experimental viscosity data.<sup>14-16</sup> Molecular dynamic provides a way to predict the viscosity of liquids mixtures<sup>13, 17,18</sup>. Without making use of experimental