# Correlating Viscosity with Temperature and Other Properties

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**ABSTRACT:** Simple viscosity equations based on linearities [$1/\eta^e$ (or $\phi^e$) vs. $T$; $T/\eta^e$ vs. $T$ and $\phi^e$ vs. $P$; ($\eta$, viscosity; $\phi$, fluidity; $T$, temperature; and $P$, any property or property function linear with $T$, such as, density, refractivity, and surface tension )] are given for glycerol, triglycerides, glyceride oils, *n*-fatty acids, esters, an alcohol, and an amine.
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**KEY WORDS:** Density, esters, *n*-fatty acids, refractivity, surface tension, triglycerides, viscosity.

Published viscosities, plentiful (1–16) for one or a few temperatures (such as those in Table 1), have limited value when viscosities are needed at temperatures other than those published ones. Proposed equations to calculate viscosities at various desired temperatures are relatively or highly complex (13–17). Equation 1, for example, was recently used to correlate viscosity with temperature for 355 compounds (16). Although equations less complex than Equation 1 are available (13,15), there is still the need for simple, even if empirical, expressions to correlate $\eta$ with temperature:

$$\text{Log } \eta = A + B/T + CT + DT^2 \qquad [1]$$

where $A$, $B$, $C$, and $D$ are regression coefficients, and $T$ is temperature in K.

The principal purpose of the present work was to enhance the usefulness of published viscosities by developing simple equations, preferably nonlogarithmic, to correlate viscosity with temperature and other properties. The advantages of such equations include ease of use, space economy (much information in little space), new data estimated by interpolation or prudent extrapolation, identification of grossly inaccurate (nonfitting) data, and evaluation of data quality (accurate data give high correlation coefficients). Compounds of special interest in the oil and fat community were selected (from the many studied successfully) for presentation in the present report.

Equations 2–5 are some of the simple equations developed to correlate viscosity ($\eta$) with temperature ($t$, °C or $T$, K) and other properties ($P$):

$$\eta = b + m/(t + k) \qquad [2]$$

$$\phi^k = b + m\,t \qquad [3]$$

$$T,\text{K}/\eta^k = b + m\,t \qquad [4]$$

$$\eta^k = b + m\,P \qquad [5]$$

where $b$ is intercept, $m$ is slope, $k$ is adjustable parameter, $\phi$ is fluidity (or $1/\eta$), and $P$ is property.

The $k$ values in Equation 3 and in the Table 2 and Table 3 equations can be used as negative exponents ($-k$) to calculate viscosities directly. Equations 3 and 4, used in developing the Tables 2–4 correlations, have the advantage their viscosity functions ($\phi^k$ and $T\text{K}/\eta^k$) are linear with properties and property functions that are temperature-linear.

Equation 3 can be transformed into Equation 6, convenient viscosity calculator:

$$\eta = [1/m/(b/m + t)]^{1/k} \text{ or } \eta = [m'/(t + k)]^{1/k} \qquad [6]$$

All alkyl groups (R) used in this paper are normal. Viscosities, mPa S, are treated as being equal to centipoise viscosities, cP (5,13).

**TABLE 1**
**Viscosities of Compounds at Different Temperatures[a]**

| $t$ (°C) | Acetic acid | Bu acetate | Et propanoate | Butane nitrile | Octanoic acid | 1-Hexanol | $BuNH_2$ | $(Et)_3N$ |
|---|---|---|---|---|---|---|---|---|
| 0 | | 1.00 | 0.691 | | | | 0.830 | 0.455 |
| 25 | 1.06 | 0.685 | 0.501 | 0.553 | 5.02 | 4.58 | 0.574 | 0.347 |
| 50 | 0.786 | 0.500 | 0.380 | 0.418 | 2.66 | 2.27 | 0.409 | 0.273 |
| 75 | 0.599 | 0.383 | 0.299 | 0.330 | 1.65 | 1.27 | 0.298 | 0.221 |
| 100 | 0.464 | 0.305 | 0.242 | 0.268 | 1.15 | 0.781 | | |

[a]References 3 and 5 provide viscosities for these and many other compounds at 0, 25, 50, 75, and 100°C.

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**TABLE 2**
***n*-Alkyl *n*-Alkanoates: Correlations Between Fluidity ($\phi = 1/\eta$) and Temperature (*t*, °C)[a,b]**

| Ester | Total carbons | Temperature range | Adj. parameter, *k* | Intercept, *b* | Slope, *m* | Correlation coefficient, *r* |
|---|---|---|---|---|---|---|
| Me ester | 7 | 10/80 | 0.70 | 0.8483 | 0.01163 | 0.9999,83 |
| Me ester | 8 | 10/80 | 0.64 | 0.7318 | 0.009936 | 0.9999,35 |
| Me ester | 9 | 10/80 | 0.67 | 0.5892 | 0.01012 | 0.999,82 |
| Me ester | 11 | 10/80 | 0.60 | 0.4748 | 0.008180 | 0.99999,56 |
| Me ester | 13 | 10/80 | 0.58 | 0.3687 | 0.007322 | 0.99999,16 |
| Et ester | 8 | 35/95 | 0.60 | 0.8004 | 0.009342 | 0.99999,08 |
| Et ester | 10 | 35/95 | 0.88 | 0.3930 | 0.01275 | 0.999,59 |
| Et ester | 12 | 35/95 | 0.54 | 0.4936 | 0.007102 | 0.9999,82 |
| Et ester | 14 | 35/95 | 0.48 | 0.4391 | 0.006071 | 0.99999,25 |
| Et ester | 16 | 35/95 | 0.65 | 0.2152 | 0.006940 | 0.9999,76 |
| Et ester | 18 | 35/95 | 0.50 | 0.2764 | 0.005639 | 0.99999,55 |
| Et ester | 20 | 35/95 | 0.49 | 0.2406 | 0.005301 | 0.9999,69 |
| R acetate | 8 | 35/95 | 0.60 | 0.7338 | 0.09286 | 0.9999,86 |
| R acetate | 10 | 35/95 | 0.58 | 0.5407 | 0.008279 | 0.99999,83 |
| R acetate | 12 | 35/95 | 0.40 | 0.5536 | 0.005600 | 0.99999,61 |
| R acetate | 14 | 35/95 | 0.55 | 0.3272 | 0.006813 | 0.99999,05 |
| R acetate | 16 | 35/95 | 0.52 | 0.2803 | 0.006147 | 0.9999,74 |
| R acetate | 18 | 35/95 | 0.55 | 0.1997 | 0.005927 | 0.99999,46 |
| R acetate | 20 | 35/95 | 0.52 | 0.1808 | 0.005484 | 0.99999,85 |

[a]Me ester data (1); Et ester and R acetate data (2).

[b]Correlation equation: $\phi^k = b + mt$, °C; where *k* is adjustable parameter, *b* is intercept, and *m* is slope.

**TABLE 3**
**Correlations Between Fluidity ($\phi = 1/\eta$) and Temperature (*t*, °C)[a,b,c]**

| | Temperature range | Adjustment parameter, *k* | Intercept, *b* | Slope, *m* | Correlation coefficient, *r* |
|---|---|---|---|---|---|
| Me oleate | 30/90 | 0.52 | 0.2712 | 0.005578 | 0.999999,84 |
| Et oleate | 30/90 | 0.50 | 0.2767 | 0.005422 | 0.999999,83 |
| Pr oleate | 30/90 | 0.49 | 0.2626 | 0.005258 | 0.9999999,77 |
| Bu oleate | 30/90 | 0.58 | 0.1791 | 0.005296 | 0.99999999,41 |
| Me oleate[c] | 20/70 | 0.59 | 0.2081 | 0.005156 | 0.9999999,61 |
| Me linoleate[c] | 20/70 | 0.63 | 0.2340 | 0.005228 | 1.000 |
| Me linoleate[c] | 20/70 | 0.65 | 0.2545 | 0.005211 | 0.9999999,75 |
| Me erucate[c] | 20/70 | 0.52 | 0.1799 | 0.004451 | 0.9999999,46 |
| Decyl thiopalmitate | 45/90 | 0.52 | 0.1092 | 0.004041 | 0.99999,36 |
| Triacetin | 0/100 | 0.42 | 0.1408 | 0.006406 | 0.999999,52 |
| Tributyrin | 0/100 | 0.49 | 0.2018 | 0.005694 | 0.999999,26 |
| Tricaprin | 45/85 | 0.47 | 0.2144 | 0.002752 | 0.99,88 |
| Trilaurin | 45/85 | 0.45 | 0.0666 | 0.004048 | 0.99999,17 |
| Trimyristin | 60/85 | 0.43 | 0.0638 | 0.003780 | 0.9999999,71 |
| Tripalmitin | 70/85 | 0.41 | 0.06467 | 0.003570 | 0.99999,89 |
| Tristearin | 75/85 | 0.45 | 0.02178 | 0.003296 | 0.9999999,07 |
| Coconut oil | 38/110 | 0.44 | 0.07733 | 0.004056 | 0.99999,58 |
| Glycerol | 25/100 | 0.22 | 0.1112 | 0.004424 | 0.9999,67 |
| Dodecanol | 25/80 | 0.32 | 0.2623 | 0.005635 | 0.9999,12 |
| Oleic acid | 24/110 | 0.39 | 0.1691 | 0.004127 | 0.999,70 |
| Lauric acid | 46/80 | 0.34 | 0.2964 | 0.004484 | 0.9999,64 |
| Stearic acid | 82/121 | 0.58 | –0.03634 | 0.004286 | 0.999,61 |
| Erucic acid | 38/110 | 0.39 | 0.1134 | 0.003788 | 0.999,75 |
| Decyl $NH_2$ | 20/80 | 0.60 | 0.4527 | 0.008984 | 0.99999,65 |

[a]Principal data sources (3–15).

[b]Correlation equation: $\phi^k = b + m\,t$, °C, where $\phi$ is fluidity, *k* is adjustable parameter, *b* is intercept, and *m* is slope.

[c]Equations are based on kinematic viscosities at 20, 40, and 70°C.

**TABLE 4**
**Correlations Between Viscosity (η,cP) and Temperatures (*t*,°C)[a,b]**

| | Temperature span, °C | Intercept, *b* | Slope, *m* | Correlation coefficient, *r* |
|---|---|---|---|---|
| Et laurate | 35/95 | 191.8 | 1.879 | 0.9999,71 |
| Dodecyl acetate | 35/95 | 184.0 | 1.902 | 0.99999,44 |
| Me oleate | 30/90 | 166.7 | 1.803 | 0.999999,43 |
| Trilaurin | 45/85 | 93.15 | 1.742 | 0.99999,35 |
| Heptyl thiolaurate | 30/90 | 152.6 | 1.702 | 0.9999,90 |
| Nonanoic acid | 24/110 | 154.8 | 1.869 | 0.9999,34 |
| Oleic acid | 60/90 | 110.3 | 1.715 | 0.9999,81 |
| Decylamine | 20/80 | 211.7 | 2.009 | 0.99999,44 |
| Corn oil | 24/110 | 95.90 | 1.599 | 0.999,90 |
| Soybean oil | 24/110 | 94.98 | 1.597 | 0.9999,15 |

[a]Principal data sources (2,9,11,14).

[b]Correlation equation: $T,K/\eta^{0.2} = b + m\ t$, °C; where *b* is intercept, and *m* is slope; the exponent 0.2 is adequate but not necessarily the best.

**TABLE 5**
**Et Laurate: Correlations Between Fluidity (ϕ = 1/η) and Other Properties (*P*)[a,b]**

| Temperature span, °C | *y* | *x* | Intercept, *b* | Slope, *m* | Correlation coefficient, *r* |
|---|---|---|---|---|---|
| 35/95 | *d* | *t*,°C | 0.8781 | –0.0007853 | –0.99999,86 |
| 20/40 | $N_D$ | *t*,°C | 0.4395 | –0.000400 | –1.000 |
| 10/100 | γ | *t*,°C | 30.05 | –0.08628 | |
| 35/95 | $\phi^{0.48}$ | *d* | 7.238 | –7.744 | –0.999999,56 |
| 35/95 | $\phi^{0.48}$ | $N_D$ | 7.110 | –15.18 | –0.99999,25 |
| 35/95 | $\phi^{0.48}$ | γ | 2.553 | –0.07032 | –0.9999,88 |

[a]Surface tensions (18), other data (2).

[b]Correlation equation: $y = b + mx$, where *d* is density; $N_D$ (or $n_D - 1$) is refractivity; γ is surface tension, and $\phi^{0.48}$ is fluidity with exponent 0.48.

The equations in Tables 2 and 3 correlate fluidities ($\phi^k$ or $1/\eta^k$) with temperature, those in Table 4 correlate $T\ K/\eta^k$ with temperature. The $\phi^k$ vs. *t* correlation is valid for both absolute (poises) and kinematic viscosities (Stokes) (Table 3). Equations 3 and 4, used satisfactorily with compounds of many types, appear to be widely applicable. The Table 5 equations correlate ethyl laurate fluidities with densities, refractivities, and surface tensions.

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