CM 5300 Advanced Transport Phenomena.

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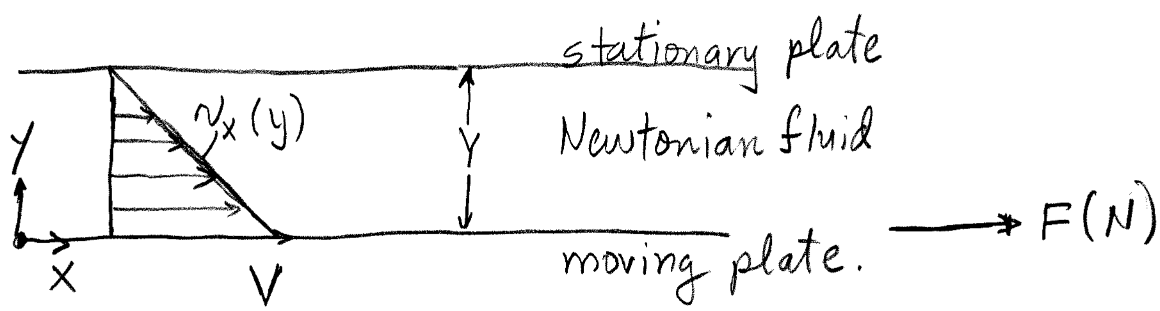
Ch 1. Viscosity – Mechanisms of Momentum Transport.

Newton's Law of Viscosity:



$v_x(y)$ – steady-state velocity distribution (profile)
a laminar profile (straight flow lines)

F/A $\left(\frac{N}{m^2}\right) \rightarrow Pa$ – a constant force per unit area of bottom plate is required to cause flow.

$$\frac{F}{A} = \mu \frac{V}{Y}$$

where μ = viscosity $(Pa \cdot s)$
(a fluid property
a resistance to flow)

"Newtonian Fluid" $\rightarrow$

$$\tau_{yx} = -\mu \frac{dv_x}{dy}$$

valid for gases + liquids up to $M = 5000$

τ_{yx} – force in x-direction per unit area $(N/m^2 = Pa)$ perpendicular to y-direction
(force is exerted by fluid of lesser y on fluid of greater y).

τ_{yx} ($N/m^2 = Pa$) – flux of x-momentum in the +y direction
↳ "flow per unit area".
(momentum flows <u>from</u> regions of high to low momentum).

$\frac{\mu}{\rho} \equiv \nu$ – kinematic viscosity (m^2/s)
where ρ = fluid density

Table 1.1-1 common units

Table 1.1-2 viscosity of water @ 1 atm

Table 1.1-3 viscosity of gases + liquids @ 1 atm

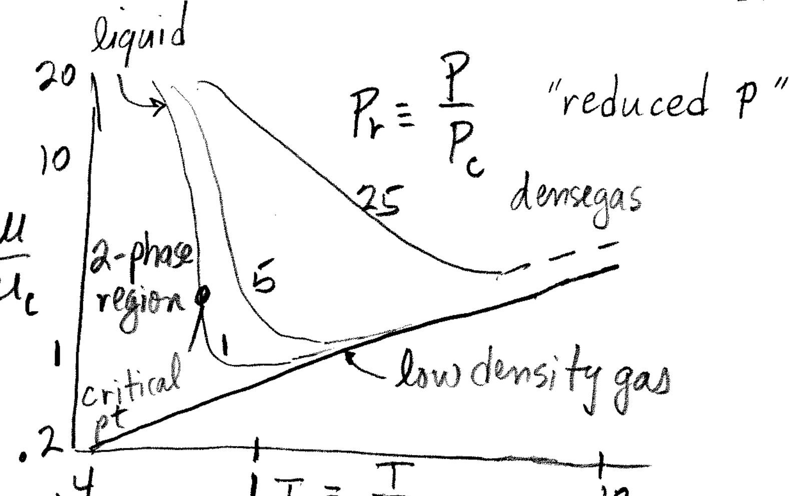
Temperature Effects: / Pressure Effects — <u>1.3</u>

gases μ increases when T increases.

liquids μ decreases when T increases.

Figure 1.3-1

"reduced μ" $\mu_r \equiv \frac{\mu}{\mu_c}$



$T_r \equiv \frac{T}{T_c}$

"reduced T"

T_c, P_c are "critical" T and P.

μ_c can be estimated from T_c, P_c, and $\tilde{V}_c$.

$$\mu_c = 61.6\,(M T_c)^{1/2}\,(\tilde{V}_c)^{-2/3} \quad \text{or}$$

$$= 7.70\, M^{1/2}\, P_c^{2/3}\, T_c^{-1/6}$$

$\tilde{V}_c$: cm^3/g-mole; P_c: atm; T_c: K

back →

See Appendix E for μ_c values.

1.4 Molecular Theory of μ of Gases at Low Density.

Kinetic Theory of Gases:

assumptions: gas composed of

- rigid, nonattracting spherical molecules of diameter, d, and mass, m.

$$\bar{u} = \sqrt{\frac{8 K T}{\pi m}}$$

molecular velocity (avg) randomly oriented.

K (kappa) — Boltzman's Constant $= 1.38066 \times 10^{-23}$ J/K

$\rightarrow = R/\tilde{N}$

R: 8.31451 J/g-mole·K "ideal gas constant"

$\tilde{N}$: 6.02214×10^{23} molecules/g-mole "Avogadro's Number"

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