FORMULA SHEET

Constants / Conversions

$R = 8.314 \frac{kPa.m^3}{kmol.K} = 8.314 \frac{J}{mol.K}$ $N_A = 6.023x10^{26} \frac{molecules}{kmol}$ $g = 9.81 m/s^2$

$R = 0.08205 \frac{atm.m^3}{kmol.K}$ $k = \frac{R}{N_A} = 1.3805x10^{-23} J/K$ $1\ cP = 10^{-3}\ Pa.s$

101.325 kPa =1 atm *1 bar = 100 kPa* *1 L = 1000 cm^3= 1000 mL = 0.001 m^3*

760 mmHg = 1 atm *1 inch = 2.54 cm*

Phase Rule

F=C+2-P

Two-Point Interpolation

$$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$$

Geometric Shapes

$V_{sphere} = \frac{4}{3}\pi r^3$ $SA_{sphere} = 4\pi r^2$ $V_{cylinder} = \pi r^2 h$

Ideal Gas

$Pv = nRT$

Kinetic Theory of Gases

$c_{mp} = \sqrt{\frac{2RT}{M}}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3RT}{M}}$ $\bar{c} = \sqrt{\frac{8RT}{\pi M}}$

$P = \frac{N_A m \overline{c^2}}{3V_m}$ $E_k = \frac{1}{2} m \overline{c^2}$ $k = \frac{R}{N_A}$

$\lambda = \frac{1}{\sqrt{2}\pi\sigma^2\rho_N}$ $\delta = \left[\frac{kT}{P}\right]^{1/3}$ $\rho_N = \frac{N_A}{V_m} = \frac{P}{kT}$

Kinetic Theory of Gases - Transport Properties

$\mu = \frac{M}{N_A \pi\sigma^2}\sqrt{\frac{RT}{\pi M}}$ $\kappa = \frac{C_v}{N_A \pi\sigma^2}\sqrt{\frac{RT}{\pi M}}$ $D_{AA} = \frac{RT}{PN_A \pi\sigma^2}\sqrt{\frac{RT}{\pi M}}$

$\mu = \frac{\rho_N \bar{c} \lambda m}{2}$ $\kappa = \frac{\lambda \rho_N \bar{c}}{2}\frac{C_v}{N_A}$

$F/A = -\mu \frac{du}{dz}$ $Q/A = -\kappa \frac{dT}{dz}$ $j_A = -D \frac{dC}{dz}$

…continued

FORMULA SHEET (continued)

$$C_v = \frac{3}{2}R \qquad C_p = \frac{5}{2}R \qquad C_p = C_v + R$$

van der Waals EOS

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2} \qquad V_m^3 - [b + \frac{RT}{P}]V_m^2 + \frac{a}{P}V_m - \frac{ab}{P} = 0$$

$$P_c = \frac{a}{27b^2} \qquad T_c = \frac{8a}{27Rb} \qquad V_c = 3b$$

$$a = \frac{27}{64}\frac{R^2T_c^2}{P_c} \qquad b = \frac{RT_c}{8P_c}$$

Mixing Rules >>> $b = \Sigma y_i b_i \qquad a = [\Sigma y_i \sqrt{a_i}]^2$

Law of Corresponding States

Pitzer-Curl

$$T_r = \frac{T}{T_c} \qquad P_r = \frac{P}{P_c} \qquad PV_m = ZRT \qquad Z = Z^{(0)} + \omega Z^{(1)}$$

Mixtures >>> $T_{pc} = \sum_i y_i T_{ci}, \quad P_{pc} = \sum_i y_i P_{ci} \qquad \overline{\omega} = \sum_i y_i \omega_i$

Volumetric Behaviour of Liquids

$$\beta_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T \qquad \alpha_P = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \qquad \gamma_V = \frac{1}{P}\left(\frac{\partial P}{\partial T}\right)_V$$

$$V_T = V_{T_o}\left(1 + A\theta + B\theta^2 + C\theta^3\right)$$

Tait's Equation

$$\beta_T = \frac{c}{P + d} \qquad \frac{V_o - V}{V_o} = c\ln\left[\frac{P + d}{d}\right]$$

Vapour-Liquid Equilibrium

Raoult's Law

$$P_{v_i} x_i = P y_i = \overline{p}_i$$

Clausius-Clapeyron

$$\frac{dP}{dT} = \frac{\Delta Hv}{T(V_g - V_l)} \qquad \ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta Hv}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad \ln(P) = -\frac{A}{T} + C$$

…continued

FORMULA SHEET (continued)

Viscosity of Liquids

Newtonian

$$\tau = -\mu \frac{du}{dy}$$

Non-Newtonian

$$\mu_{app} = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

Power Law

$$\tau = K\left(\frac{du}{dy}\right)^n$$

Kinematic Viscosity

$$\nu = \mu/\rho$$

Temperature Dependence

$$\ln(\mu) = -\frac{A}{T} + C$$

Flow of Fluids in Pipes

$$\mathrm{Re} = \frac{D\bar{u}\rho}{\mu}$$

$$Q = \bar{u}A = \bar{u}\frac{\pi D^2}{4}$$

$$Power = Q\Delta P$$

Ideal (Bernoulli)

$$\frac{P}{\rho} + gh + \frac{u^2}{2} = Const.$$

$$\frac{\Delta P}{\rho} + g\Delta h + \frac{\Delta u^2}{2} = 0$$

Laminar

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{32\mu\bar{u}}{D^2}$$

Turbulent

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2f\bar{u}^2\rho}{D}$$

Density of Solids

$$SimpleCubicMaterials = \frac{m}{d^3}$$

$$FCC\ materials = \frac{\sqrt{2}m}{d^3}$$

$$BCC\ materials = 1.299\frac{m}{d^3}$$

$$HCP\ materials = \frac{\sqrt{2}m}{d^3}$$

Lennard Jones Potential

$$\Phi(r) = 4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right]$$

$$F(r) = \frac{d\Phi(r)}{dr}$$

$$\Phi(r) = \int_{\infty}^{r} F(r)dr$$

$$\Phi(r) = \Phi(r)_r + \Phi(r)_a$$

$$b_o = \frac{2\pi}{3}\sigma^3 N_A$$

…continued

FORMULA SHEET (continued)

Thermal Expansion of Solids

$$\alpha_L = \frac{1}{L}\frac{dL}{dT}$$

Heat Conduction

Fourier's Law

$$Q = -\kappa A\frac{dT}{dx} = -\kappa A\frac{\Delta T}{\Delta x}$$

Composite Planar Wall

$$Q = \frac{-A\ \Delta T}{\left[\frac{\Delta x_1}{\kappa_1} + \frac{\Delta x_2}{\kappa_2} + \frac{\Delta x_3}{\kappa_3} + ...\right]}$$

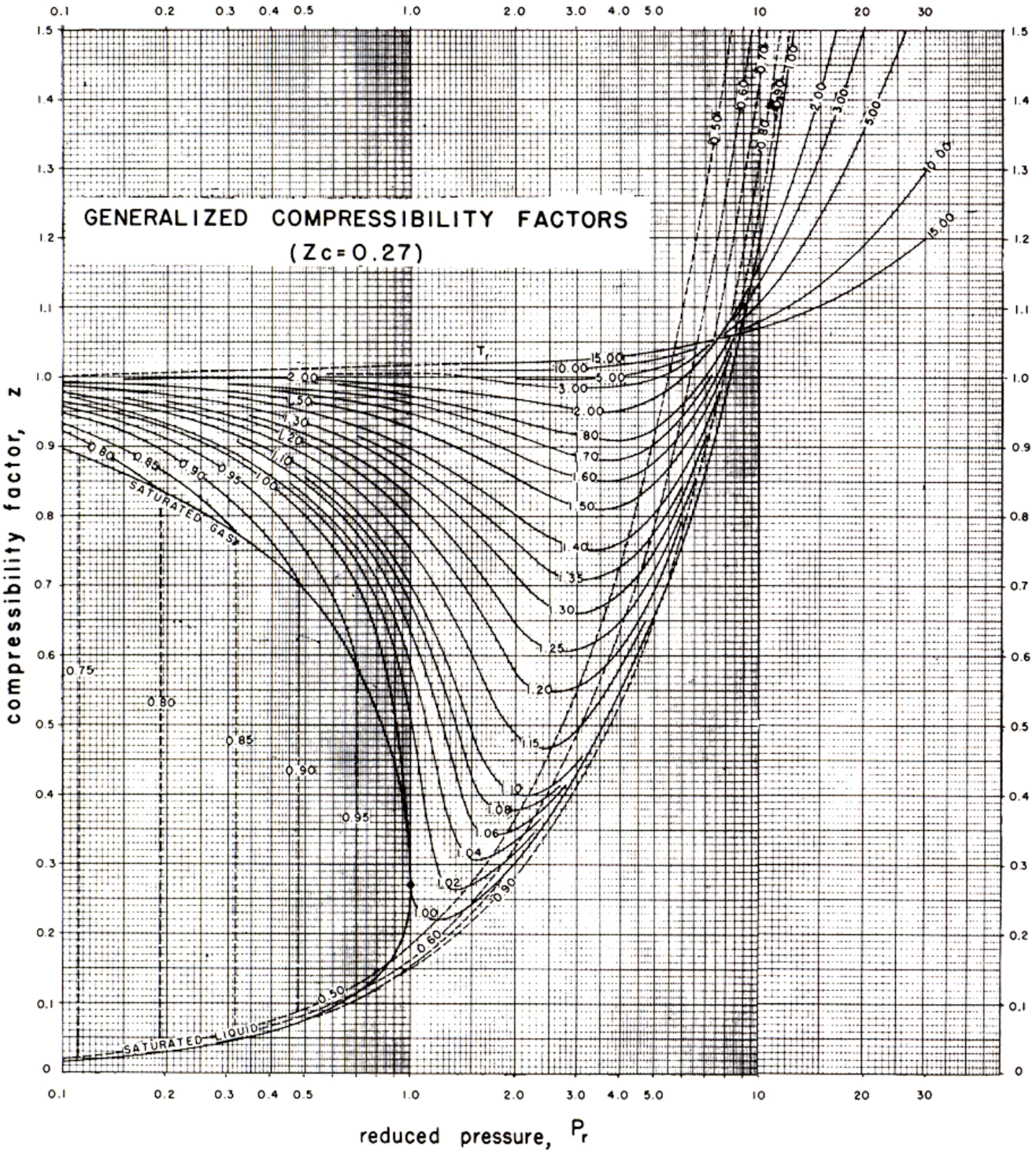
Simple Cylinder

$$Q = \frac{-2\pi\kappa L\ \Delta T}{\ln\left(\frac{r_2}{r_1}\right)}$$

Composite Cylinder (Pipe)

$$Q = \frac{-2\pi L\Delta T}{\frac{\ln(r_2/r_1)}{\kappa_1} + \frac{\ln(r_3/r_2)}{\kappa_2} + \frac{\ln(r_4/r_3)}{\kappa_3} + ...}$$

GENERALIZED COMPRESSIBILITY CHART



PITZER-CURL TABLES

Table C-1
Pitzer-Curl Generalized $Z^{(0)}$

	Pr														
Tr	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
0.80	0.851	0.066	0.100	0.133	0.164	0.192	0.255	0.258	0.287	0.318	0.347	0.376	0.405	0.433	0.461
0.85	0.882	0.067	0.101	0.134	0.165	0.194	0.226	0.258	0.287	0.316	0.345	0.374	0.403	0.431	0.459
0.90	0.904	0.778	0.102	0.135	0.167	0.198	0.229	0.258	0.288	0.316	0.345	0.373	0.402	0.430	0.458
0.95	0.920	0.819	0.697	0.145	0.176	0.205	0.235	0.262	0.292	0.321	0.347	0.375	0.403	0.430	0.457
1.00	0.932	0.849	0.756	0.638	0.291	0.231	0.250	0.278	0.304	0.329	0.356	0.381	0.407	0.433	0.458
1.05	0.942	0.874	0.800	0.714	0.609	0.470	0.341	0.320	0.332	0.350	0.372	0.393	0.417	0.441	0.446
1.10	0.950	0.893	0.833	0.767	0.691	0.607	0.512	0.442	0.408	0.402	0.405	0.420	0.440	0.462	0.484
1.15	0.958	0.98	0.858	0.805	0.746	0.684	0.620	0.562	0.514	0.484	0.477	0.478	0.485	0.498	0.513
1.20	0.963	0.921	0.879	0.835	0.788	0.737	0.690	0.640	0.598	0.568	0.553	0.545	0.544	0.548	0.554
1.25	0.968	0.930	0.896	0.858	0.820	0.778	0.740	0.702	0.664	0.636	0.618	0.606	0.599	0.597	0.598
1.30	0.971	0.940	0.909	0.878	0.846	0.811	0.780	0.749	0.718	0.691	0.671	0.657	0.649	0.644	0.642
1.4	0.977	0.952	0.929	0.908	0.883	0.859	0.838	0.817	0.795	0.777	0.759	0.745	0.734	0.725	0.720
1.5	0.982	0.963	0.945	0.927	0.909	0.892	0.875	0.859	0.844	0.831	0.819	0.808	0.800	0.794	0.790
1.6	0.985	0.971	0.957	0.944	0.930	0.917	0.904	0.893	0.882	0.872	0.863	0.855	0.848	0.843	0.840
1.7	0.988	0.977	0.966	0.956	0.946	0.936	0.926	0.919	0.911	0.903	0.896	0.869	0.889	0.883	0.879
1.8	0.991	0.982	0.974	0.966	0.958	0.950	0.944	0.937	0.931	0.926	0.921	0.916	0.913	0.910	0.908
1.9	0.993	0.986	0.980	0.974	0.968	0.962	0.958	0.952	0.948	0.944	0.940	0.936	0.933	0.931	0.930
2.0	0.995	0.989	0.984	0.979	0.975	0.971	0.968	0.964	0.961	0.959	0.956	0.954	0.953	0.953	0.952

Table C-2
Pitzer-Curl Generalized $Z^{(1)}$

	Pr														
Tr	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
0.80	−0.095	−0.028	−0.044	−0.058	−0.07	−0.08	−0.10	−0.11	−0.12	−0.13	−0.14	−0.15	−0.16	−0.17	−0.18
0.85	−0.067	−0.031	−0.049	−0.064	−0.08	−0.09	−0.11	−0.12	−0.13	−0.14	−0.15	−0.16	−0.17	−0.18	−0.18
0.90	−0.042	−0.09	−0.053	−0.068	−0.085	−0.10	−0.11	−0.12	−0.13	−0.14	−0.15	−0.16	−0.17	−0.17	−0.18
0.95	−0.025	−0.050	−0.100	−0.072	−0.091	−0.10	−0.11	−0.12	−0.12	−0.13	−0.14	−0.15	−0.15	−0.16	−0.17
1.00	−0.012	−0.16	−0.20	−0.05	−0.080	−0.090	−0.099	−0.108	−0.115	−0.123	−0.13	−0.13	−0.14	−0.14	−0.15
1.05	0.000	+0.001	+0.005	+0.015	+0.02	+0.01	−0.01	−0.04	−0.06	−0.07	−0.08	−0.09	−0.10	−0.11	
1.10	+0.002	0.008	0.016	0.030	0.055	0.082	+0.11	+0.082	+0.035	0.000	−0.02	−0.03	−0.05	−0.06	−0.07
1.15	0.004	0.012	0.012	0.040	0.064	0.093	0.12	0.140	0.136	+0.100	+0.07	+0.04	+0.02	0.00	−0.01
1.20	0.009	0.018	0.028	0.044	0.069	0.10	0.13	0.16	0.17	0.17	0.16	0.14	0.12	+0.09	+0.07
1.25	0.011	0.023	0.036	0.050	0.069	0.10	0.13	0.16	0.18	0.19	0.19	0.18	0.16	0.14	0.12
1.30	0.013	0.027	0.041	0.055	0.072	0.10	0.13	0.16	0.18	0.20	0.20	0.20	0.20	0.19	0.18
1.4	0.016	0.032	0.049	0.065	0.082	0.10	0.13	0.16	0.18	0.19	0.20	0.21	0.21	0.21	0.20
1.5	0.017	0.035	0.052	0.070	0.088	0.10	0.13	0.15	0.17	0.18	0.20	0.20	0.21	0.21	0.21
1.6	0.018	0.036	0.054	0.07	0.08	0.10	0.12	0.14	0.16	0.17	0.18	0.19	0.20	0.20	0.21
1.7	0.018	0.036	0.054	0.07	0.09	0.10	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.20	0.21
1.8	0.018	0.036	0.054	0.07	0.09	0.10	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.20	0.21
1.9	0.018	0.035	0.05	0.07	0.09	0.10	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.20	0.21
2.0	0.016	0.031	0.05	0.07	0.08	0.10	0.11	0.13	0.14	0.15	0.16	0.17	0.19	0.20	0.21

FRICTION FACTOR CHART