Problem Set No. 5

Due: Monday, February 7, 2011

Objective: To understand and perform calculations using PVT equations of state.

Note: Numerical values for some problems have been changed from those in the book.

Problem 19 (thought problem)

A dilute gas is well-described by a short virial expansion of the form,

$$Z = 1 + \frac{B}{V}$$

where Z is the compressibility factor and B the second virial coefficient, which has been measured in experiment and is known.

a) Let's say you want to find $V(T, P)$, i.e., solve for the molar volume if T and P are known. What order is the equation that you must solve? How many roots are there?

b) Find an expression for the roots $V(T, P)$. Are all physically relevant? Why or why not?

c) At constant temperature T, this gas is compressed to half its volume. Find an expression for the work per mol required, in terms of T, V_1, and B.

Problem 20 (*Smith, van Ness, Abbott, 3.4, page 111)*

Liquid water's isothermal compressibility can be well-approximated by the following equation:

$$\kappa = \frac{c}{V(P + b)}$$

where c and b are functions of temperature only. If 1 kg of water is compressed isothermally and reversibly from 1 to 400 bar at 60 °C, how much work is required? At 60 °C, $b = 2700$ bar and $c = 0.125\ \mathrm{cm}^3/\mathrm{g}$.

Problem 21 (*Smith, van Ness, Abbott, 3.34b,c,d, page 118)*

Calculate Z and V (**in cm^3/mol**) for sulfur hexafluoride at 75 °C and 15 bar by the following four methods:

(a) The truncated virial equation [Eq. (3.38)] with a value of B from the generalized Pitzer correlation [Eq. (3.63)].

(b) The Redlich/Kwong equation.

(c) The Soave/Redlich/Kwong equation.

(d) The NIST Chemistry Webbook* at http://webbook.nist.gov/chemistry/fluid/

For sulfur hexafluoride, $T_C = 318.7\ K, P_C = 37.6\ \text{bar}, V_C = 198\ cm^3/mol$ and $\omega = 0.286$.

Problem 22 (*Smith, van Ness, Abbott, 3.35ac, page 118)*

Determine Z and V (**in $\boldsymbol{cm^3/mol}$**) for steam at 250 °C and 1,800 kPa by the following:

(a) The truncated virial equation [Eq. 3.40] with the following experimental values of virial coefficients: $B = -152.5\ \text{cm}^3/\text{mol}$ and $C = -5{,}800\ \text{cm}^6/\text{mol}^2$.

(b) The steam tables [App. F].

(c) The NIST Chemistry Webbook* at http://webbook.nist.gov/chemistry/fluid/.

Problem 23 (*Smith, van Ness, Abbott, 3.38i, page 118)*

Consider saturated n-butane (two-phase liquid-vapor coexistence) at $120\ ℃$ where $P^{\text{sat}} = 22.38\ \text{bar}$. Calculate the molar volume of saturated liquid and the molar volume of saturated vapor, both **in $\boldsymbol{cm^3/mol}$**, by the following three methods:

(a) The Redlich-Kwong equation.

(b) Suitable generalized correlations.

(c) The NIST Chemistry Webbook* at http://webbook.nist.gov/chemistry/fluid/.

Problem 24 (*Smith, van Ness, Abbott, 3.47, page 120*)

To what pressure does one fill a 0.15 m^3 vessel at 25 ℃ in order to store $40\ kg$ of ethylene in it? (You will need to choose an appropriate model to determine an answer; do not use tabulated data.)

* If you are having trouble seeing results in your browser, you may need to unselect the option "Check here if you want to use the display applet (requires Java capable browser)" at the NIST Chemistry Webbook site.