Chemistry 2290, Winter 2012, G. Schreckenbach
Practice problems –2–

Real gases, continued

Other practice problems *(courtesy J. van Wijngaarden)*

3.1 At 273 K, measurements of Ar gas give the following values for the 2nd and 3rd virial coefficients: $B(T) = -21.7 \text{ cm}^3 \text{ mol}^{-1}$; $C(T)$ 1200 $\text{cm}^6 \text{ mol}^{-2}$. Estimate the molar volume V_m of Ar using the following approximation method:
   (i) By first assuming that the gas behaves ideally, get an initial estimate for V_m.
   (ii) Express the Virial Equation of State as $V_m = \dfrac{RT}{P}\left[1 + correction \ terms\right]$ and substitute your V_m from part (i) into the r.h.s. of the virial equation (i.e. into the *correction terms)* to obtain a second, improved estimate for V_m.
   (iii) Take your second estimate from part (ii) and substitute it again into the virial equation. If one were to continue this recipe for several iterations, one would approach an accurate value (*accurate up to 3rd order if only B(T) and C(T) are included*) for V_m.
3.2 As discussed in class, the 2nd virial coefficient is approximately a function of the van der Waals constants. Using this information and the van der Waals constants as listed in the textbook, calculate the Boyle temperature of Ar.
3.3 Using the Law of Corresponding States, find the set of conditions for which N_2 and CO_2 are in states corresponding to: $P_R=0.196$; $V_{R,m}=20.0$; $T_R=1.50$.
3.4 Using the Law of Corresponding States, what is the temperature of NH_3 at a pressure of 150.atm and a molar volume of 0.35 L mol^{-1}. Compare your result to the ideal gas value.

First Law

Engel and Reid, 2nd ed.:
Questions on concepts: Q2.2, Q2.4, Q2.6, Q2.11, Q2.12
Problems: P2.1, P2.2, P2.3, P2.6, P2.7, P2.8, P2.12, P2.14, P2.16, P2.19, P2.20, P2.21, P2.22, P2.26, P2.27, P2.28, P2.29, P2.30, P2.33, P2.34, P2.37, P2.38

Note: The above is a sample of questions and problems – there are many other good examples in Engel & Reid. So, if you want more practice, by all means do extra problems!!!

Practice problems from Laidler/ Meiser
(Problems adapted from Laidler, Meiser, Sanctuary, Physical Chemistry, 4th ed., Houghton Mifflin)

LM6. The densities of ice and water a 0ºC are 0.9168 and 0.9998 g cm^{-3}, respectively. If ΔH_m for the fusion process at atmospheric pressure is 6.025 kJ mol^{-1}, what is ΔU_m? How much work is done on the system?
LM7. The density of liquid water at 100ºC is 0.9584 g cm^{-3}, and that of steam at the same temperature is 0.000 596 g cm^{-3}. If the enthalpy of evaporation of water at atmospheric

pressure is 40.63 kJ mol^{-1}, what is ΔU? How much work is done during the evaporation process?

LM8. The latent heat of fusion of water at 0°C is 6.025 kJ mol^{-1} and the molar heat capacities $C_{p,m}$) of water and ice are 75.3 and 37.7 J K^{-1} mol^{-1}, respectively. The C_p values can be taken to be independent of temperature. Calculate ΔH for the freezing of 1.00 mol of supercooled water at –10.0°C.

LM9. When 1 cal of heat is given to 1.00 g of water at 14.5°C, the temperature rises to 15.5°C. Calculate the molar heat capacity of water at 15°C. *(Assume 3 significant figures.)*

LM10. Two (2.00) moles of oxygen gas are initially at 273 K in a volume of 11.35 L. Consider the gas as ideal; heat capacity $C_{p,m} = 29.4$ J K^{-1} mol^{-1}. Suppose the gas is heated reversibly at constant volume to 373 K:
  (a) How much work is done on the system?
  (b) What is the increase in internal energy, ΔU?
  (c) How much heat was added to the system?
  (d) What are the initial and final pressures?
  (e) What is the change in enthalpy, ΔH?

LM11. Suppose the gas in problem LM10 is heated reversibly at constant pressure to 373 K:
  (a) What is the final volume?
  (b) How much work is done on the system?
  (c) How much heat is supplied to the system?
  (d) What is the change in enthalpy?
  (e) What is the change in internal energy?

LM12. Suppose the gas in problem LM10 is reversibly compressed to half its original volume at constant temperature (273 K):
  (a) What is the change in internal energy?
  (b) What is the final pressure?
  (c) How much work is done on the system?
  (d) How much heat is given off *by the system*?
  (e) What is the change in enthalpy?

LM13. A sample of hydrogen gas, which may be assumed to behave ideally, is initially at 3.0 bar pressure and at a temperature of 25.0°C, and has a volume of 1.5 dm^3. It is expanded reversibly and adiabatically until the volume is 5.0 dm^3. The heat capacity C_{pm} of H$_2$ is 28.80 J K^{-1}mol^{-1}, and may be assumed to be independent of temperature.
  (a) Calculate the final pressure and temperature after the expansion.
  (b) Calculate ΔU and ΔH for the process.

LM14. A gas that behaves ideally was allowed to expand reversibly and adiabatically to twice its volume. Its initial temperature was 25.00°C, and $C_{V,m} = (5/2)R$. Calculate ΔU_m and H_m for the process.