Chemistry 160
Test 2-a

Name KEY

stronger IPFs

1) (2.5 points) Which member in each pair has the lower vapor pressure at a given temperature? Circle your choice.

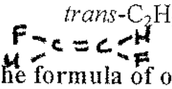
more polarizable e^-s

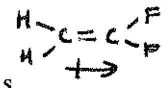
a) K or [✓ Fe] b) [✓ I_2] or Xe c) CsBr or [✓ KBr]

K^+ has a greater charge density

d) [✓ CH_3CH_2OH] or CH_3CH_2F e) *trans*-$C_2H_2F_2$ or [✓ *cis*-$C_2H_2F_2$]

H-bonding





2) (1.5 points) From the substances given in question 1, write the formula of one substance that forms

a) an atomic solid b) a molecular solid c) an ionic solid

K, Fe, Xe

I_2, CH_3CH_2OH, CH_3CH_2F, trans+cis $C_2H_2F_2$

CsBr, KBr

3) (4 points) Helium has two liquid forms, He I and He II. He II is a superfluid with no viscosity. Helium also has solids that are hcp and bcc depending on the conditions. On the given phase diagram for He

a) Identify the triple points. Circle your choices.

b) What forms exist at each triple point?

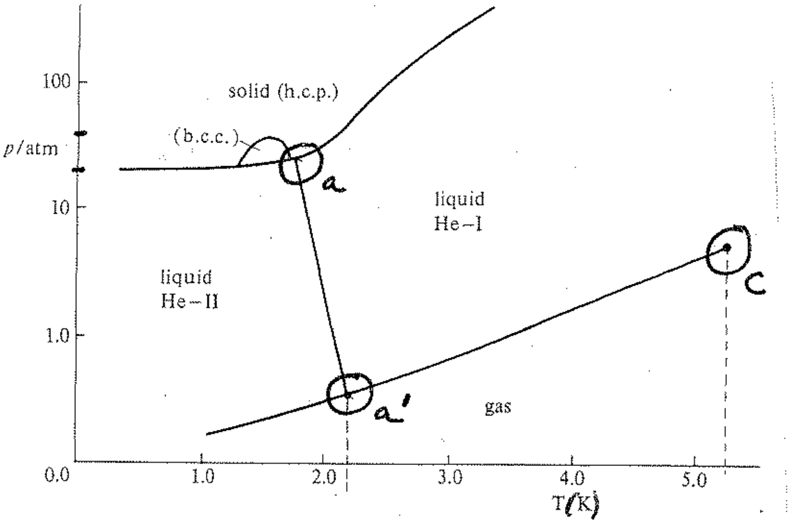
a : s (hcp), l (He I), l(He-I

a' : l (He-I), l(He-II), g

c) Identify the critical point. Circle your choice.

d) You have He II at 1.5 K. How would you produce solid He in bcc form? Increase the pressure to ~ 30 atm

e) Why can't increased pressure beyond the critical point liquefy He? Too much kinetic energy

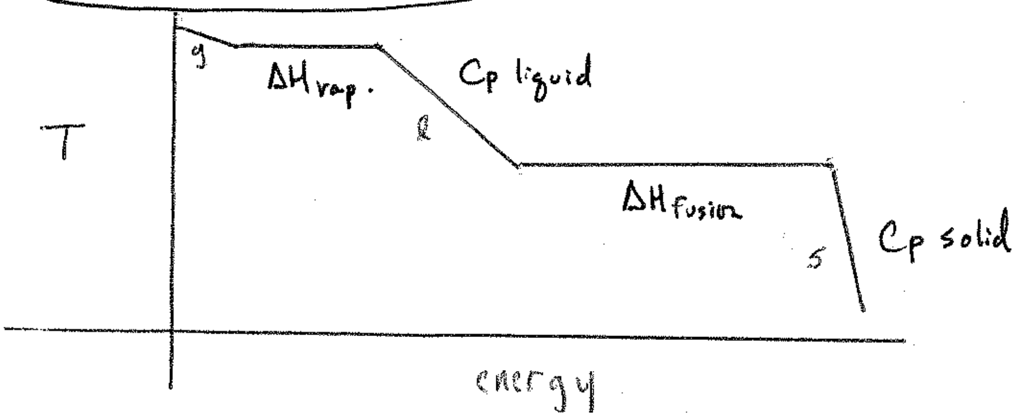


4) (1.5 points) For the given cooling curve of a certain mass of material determine the larger quantity. Circle your choice.

a) C_p of the solid or [✓ C_p of the liquid] → For the same mass and the same ΔT (compared to Cp solid) the energy change is the greatest.

b) [✓ ΔH_{fusion}] or $\Delta H_{vaporization}$

c) [✓ total energy removed for certain mass] or total energy removed for ½ the certain mass



5) (2.5 points) Which of the following will have the lowest total vapor pressure at 25 °C?

a) (P_{vap} (H_2O) = 23.8 torr at 25 °C)
b) a solution glucose in water with $\chi_{C6H12O6}$ = 0.01 $\chi_{H_2O} = 0.99$ $P' = \chi_{H_2O}(23.8 \text{ torr}) = 23.6 \text{ torr}$
[✓ c)] a solution of NaCl in water with χ_{NaCl} = 0.01 $\longrightarrow \chi_{ions} = 0.02,\ \chi_{H_2O} = 0.98,\ P' = 23.3 \text{ torr}$
d) a solution of methanol and water with χ_{CH3OH} = 0.2, (P_{vap} (CH_3OH) = 143 torr at 25 °C)

$$P' = \chi_A P_A + \chi_B P_B = 0.2\,(143 \text{ torr}) + 0.8\,(23.8 \text{ torr}) = 47.6 \text{ torr}$$

6) (14 points) A solution containing a high molar mass biomolecule solute and CCl_4 solvent is 88.2_{353} % CCl_4 by mass. The mass of CCl_4 is 15.0 g. The boiling point of this solution was 77.85 °C. The boiling point constant and the boiling point for pure CCl_4 are 5.03 °C/m and 76.50 °C, respectively.

a) Calculate the molar mass of the biomolecule.
b) Calculate the mole fraction of CCl_4 in the solution.
c) Calculate the vapor pressure of the solution at 20 °C. The vapor pressure of pure CCl_4 at 20 °C is 91.3 torr.
d) What would be the vapor pressure of CCl_4 at 76.50 °C? $\hookrightarrow$ 760 torr or 1atm

Extra Credit: Calculate the actual vapor pressure at 76.50 °C using the Claussius-Clapeyron Equation. It may be different from 6d, that's ok.

a) [redacted] $0.882_{353} = \dfrac{15.0\,g}{x + 15.0\,g} \longrightarrow$ [redacted] $0.882_{353}x + 13.2_{3539} = 15.0\,g$

$x = 1.9_{99}\ g = \boxed{2.0\,g \text{ biomolecule}}$

$$\Delta T_b = (77.85 - 76.50)^\circ C = 1.35\,^\circ C$$

$$\Delta T_b = K_b m$$

$$1.35^\circ C = 5.03\,\frac{^\circ C}{m}\,\cancel{m} \longrightarrow x = 0.268_{39}\ m \longrightarrow x = \frac{0.268_{39}}{Kg}\text{ mol biomolecule}$$

$$\frac{0.268_{39}\text{ mol biomolecule}}{1\,\cancel{Kg}} \times \frac{15.0\,\cancel{g}}{1000\,\cancel{g}}\bigg|\,\frac{1\,\cancel{Kg}}{} = 4.02_{58} \times 10^{-3}\text{ mol biomolecule}$$

$$MM_{Biomolecule} = \frac{2.0\,g}{4.02_{58} \times 10^{-3}\text{ mol}} = \boxed{4.9_7 \times 10^2\ g/mol}$$

b.) mol of biomolecule $= 4.02_{58} \times 10^{-3}$ mol

mol of $CCl_4 = \dfrac{15.0\,g}{1}\bigg|\dfrac{1\text{mol } CCl_4}{153.823\,g} = 0.0975_{15}$ mol

$$\boxed{\chi_{CCl_4} = \frac{0.0975_{15}}{0.0975_{15} + 4.02_{58} \times 10^{-3}} = 0.960_4}$$

c) $P' = \chi_{CCl_4} P^\circ = 0.960_4 \times 91.3 \text{ torr} = \boxed{87.7 \text{ torr}}$

7) (4 points) When pure methanol (CH_3OH) is mixed with water the resulting solution feels warm. Would you expect this solution to be ideal? Explain what must occur for the solution to form (consider both enthalpy and entropy) and why it is exothermic and why methanol is soluble in water. Both methanol and water are volatile.

No. While solution formation is entropically favored ($\Delta S > 0$, # of μ-states increases) it may be energetically favored (exothermic) or disfavored (endothermic). The energy involved in the solution process is a trade off between the energy needed to separate pure solvent + pure solute (endothermic) and that produced when solvent + solute interact (exothermic). In this case the solution releases more energy than the solute + solvent separation requires. $\longrightarrow$

EC : 20°C 91.3 torr
76.50°C X

$$\ln\left(\frac{91.3}{X}\right) = \frac{32.4}{(8.314\times10^{-3})}\left(\frac{1}{76.50+273.15} - \frac{1}{20+273.15}\right)$$

X = 782 torr ≈ 760 torr

This can be expected because both methanol + water are capable of hydrogen bonding. Having the solute + solvent with similar IPFs is beneficial for dissolving.