Spring 2008 CH 302Worksheet 2

1. 100 g of ice at -25°C is heated to steam at 125°C. For water, the specific heats are c_{ice} = 2.093 J/g°C, c_{water} = 4.186 J/g°C, and c_{steam} = 2.009 J/g°C. The enthalpy changes are ΔH_{fusion} = -335.5 J/g and $\Delta H_{vaporization}$ = 2.26 kJ/g. What is ΔH_{sys} for this process?

   Answer: Divide the process into several steps:

   Heat ice to 0°C: $\Delta H = mc\Delta T$ = (100 g)(2.093 J/g°C)(25°C) = 5.232 kJ
   Melt ice: $\Delta H = -m\Delta H_{fusion}$ = -(100 g)(-335.5 J/g) = 33.55 kJ
   Heat water to 100°C: $\Delta H = mc\Delta T$ = (100 g)(4.186 J/g°C)(100°C) = 41.86 kJ
   Boil water: $\Delta H = m\Delta H_{vaporization}$ = (100 g)(2.26 kJ/g) = 226 kJ
   Heat stem to 125°C : $\Delta H = mc\Delta T$ = (100 g)(2.009 J/g°C)(25°C) = 5.0225 kJ

   So the total ΔH = 5.232 kJ + 33.55 kJ + 41.86 kJ + 226 kJ + 5.0225 kJ = **312 kJ**.

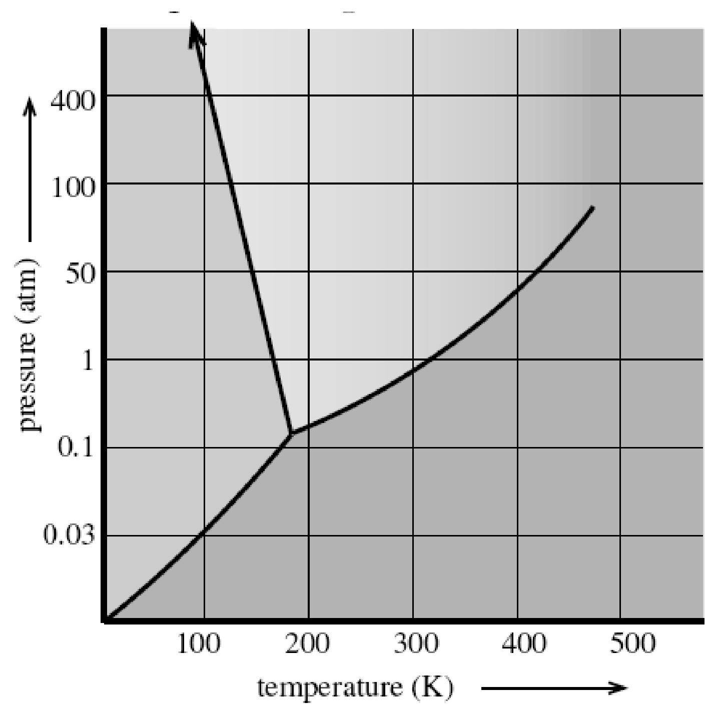
2. 1 MJ of heat is dumped into 2 kg of ice at -25°C. What is the final temperature and state (solid, liquid, or gas) of the water?

   Answer: First, see how much energy it takes to melt the ice:

   Heat ice to 0°C: $\Delta H = mc\Delta T$ = (2000 g)(2.093 J/g°C)(25°C) = 104.65 kJ
   Melt ice: $\Delta H = -m\Delta H_{fusion}$ = -(2000 g)(-335.5 J/g) = 671.00 kJ

   ΔH for this process = 104.65 + 671.00 kJ = 775.65 kJ. So we have 1000 kJ – 775.65 kJ = 224.35 kJ. So we solve for how much we can increase the temperature of the water with this amount of heat.

   Heat water to T_f: $\Delta H = mc(T_f - 0°C)$
   $T_f = \Delta H/mc$ = 224350 kJ/(2000 g * 4.186 J/g°C) = **26.8°C**



3. The phase diagram for water (shamelessly borrowed from last year's quiz 2) is shown above. (a) What phase change(s) occur when going from 1 atm, 100 K to 1 atm, 400K? (b) From 0.1 atm, 100 K to 0.1 atm, 400K?

   Answer: (a) melting, then vaporization; (b) sublimation

4. For any temperature less than ~475 K, if you keep increasing the pressure on the system, what will be the eventual state of the system? Is this the same or different from most other substances?

   Answer: Liquid. Different; for most substance, the eventual state of the system will be solid.

5. Describe the physical state of the system (a) at the point where the three lines meet, and (b) at temperatures above ~475K.
Answer: (a) All three states are present in equilibrium. (b) The water is a supercritical fluid – it is no longer possible to distinguish between gas and liquid.

6. Give a basic explanation for the well-known rule "like dissolves like."
Answer: A solute molecule replaces solvent molecules. It is much less disruptive to the intermolecular forces at work if the solute molecule has similar intermolecular forces to the solvent molecules it replaces.

7. Describe the structure formed by soap molecules around a grease molecule.
Answer: The nonpolar tails of the soap molecules orient themselves toward the nonpolar grease molecule and solvate it; the polar heads of the molecules then form a sphere around the micelle and are solvated by the polar water.

8. Which of the following will be most miscible in water: methanol (CH_3OH), ethanol (CH_3CH_2OH), propanol ($CH_3CH_2CH_2OH$), butanol ($CH_3CH_2CH_2CH_2OH$).
Answer: Methanol; it has the smallest nonpolar alkyl tail.

9. Which of the above alcohols will be most miscible in hexane (C_6H_{12})?
Answer: Butanol; Hexane is nonpolar, so it is most miscible with other nonpolar molecules. Butanol has the largest nonpolar tail relative to the polar –OH group.

10. At 0°C, the vapor pressure of acetone is 0.095 atm, and at 20°C, the vapor pressure is 0.243 atm. What is the enthalpy of vaporization of acetone?
Answer: $\ln(P_2/P_1) = \Delta H/R(1/T_1 - 1/T_2)$

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\begin{aligned}
\Delta H &= R \ln(P_2/P_1)\,(1/T_1 - 1/T_2)^{-1} \\
&= (8.314 \text{ J/molK}) \ln(0.243 \text{ atm}/0.095 \text{ atm})\,(1/273 \text{ K} - 1/293 \text{ K}) \\
&= 31.3 \text{ kJ}
\end{aligned}
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11. Using the information from the above problem, what is the boiling point of acetone?
Answer: Boiling occurs when the vapor pressure equals 1 atm.

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\begin{aligned}
1/T_2 &= 1/T_1 - R/\Delta H \ln(P_2/P_1) \\
&= 1/273 \text{ K} - (8.314 \text{ J/molK})/(31300 \text{ kJ}) \ln(1 \text{ atm}/0.095 \text{ atm}) \\
&= 0.00304 \text{ K}^{-1} \\
T_2 &= \underline{\mathbf{329\ K = 56°C}}
\end{aligned}
$$

12. Rank the following in terms of increasing ability to increase the boiling point of water: NaCl, sugar, $CaCl_2$, BaS.
Answer: BaS < sugar < NaCl < $CaCl_2$. List in terms of increasing number of "things" dissolved for each molecule of the substance. BaS is insoluble in water.

13. Rank the osmotic pressure in increasing order when 1 mol of each of the compounds in #12 is dissolved in water.
Answer: Same ranking as above. Osmotic pressure increases as the number of "things" dissolved increases.

14. At room temperatures, he vapor pressures of ethylene glycol ($HOCH_2CH_2OH$) and water (H_2O) are 0.06 torr and 17.54 torr, respectively. What is the vapor pressure of a mixture of 500 mL of ethylene glycol and 500 mL of water? Assume the densities of the two liquid are the same (1 g/mL).

Answer: Find the number of moles and mole fractions:

$n_{e.g.}$ = 500 mL * 1 g/mL * 1 mol/62 g = 8.065 mol
n_{water} = 500 mL * 1 g/mL * 1 mol/18 g = 27.778 mol
$\chi_{e.g.}$ = mol e.g./(mol e.g. + mol water)
= (8.065 mol)/(8.065 mol + 27.778 mol) = 0.225
χ_{water} = 1 – 0.225 = 0.775

Then the vapor pressure is

$P_{tot} = P_{e.g.} + P_{water}$ = (0.06 torr)(0.225) + (17.54 torr)(0.775) = **13.6 torr**

15. A 1 L mixture of ethylene glycol and water has a vapor pressure of 10 torr. What is the volume of ethylene glycol in the mixture?

Answer: $P_{tot} = p_{e.g.}\chi_{e.g.} + p_{water}\chi_{water} = p_{e.g.}\chi_{e.g.} + p_{water}(1-\chi_{e.g.})$
10 torr = (0.06 torr)χe.g. + (17.54 torr)$(1-\chi_{e.g.})$
$\chi_{e.g.}$ = 0.43135
= mol e.g./(mol e.g. + mol water)
= (Ve.g. 1 g/mL 1 mol/62 g)/[(Ve.g. 1 g/mL 1 mol/62 g)+ ((1000 mL - Ve.g.) 1 g/mL 1 mol/62 g)
$V_{e.g.}$ = **723 mL**

16. Give a simple explanation for the depression of the vapor pressure of water by the addition of a solute.

Answer: When a solute is added, there is less water at the surface of the solution than in pure water.

17. 5 g of table salt (NaCl) are dissolved in 100 mL of water. What is the vapor pressure of the solution, given P° = 17.54 torr?

Answer: Find the number of moles of salt and water.

n_{salt} = 5 g * (1 mol/58.5 g) = 0.08547 mol
n_{water} = 100 mL * (1 g/mL) * (1 mol/18 g) = 5.556 mol

The mole fraction is then $\chi_{salt} = n_{salt}/(n_{salt} + n_{water})$ = 0.08547 mol/(0.08547 mol + 5.556 mol) = 0.01515

So ΔP = i * χ_{salt}P° = 2(0.01515)(17.54 torr) = 0.5316 torr

P = 17.54 torr – 0.5316torr = ~~**17.01 torr**~~

18. What is the freezing point of the solution, given K_f = 1.86 °C/molal?

Answer: The molality of the solution is

$m_{salt} = n_{salt}/m_{water}$ = 0.08547 mol/0.100 kg = 0.8547 molal

So $\Delta T_f = -imK_f$ = -2(0.8547 molal)(1.86 °C/molal) = -3.18°C

T_f = 0°C – 3.18°C = ~~**-3.18 °C**~~

19. What is the change in osmotic pressure of the solution at 298 K? Assume the salt contributes negligibly to the volume.

Answer: The molarity is $M_{salt} = n_{salt}/V_{soln}$ = 0.08547 mol/0.1 L = 0.8547 molar

So π = iMRT = 2(0.8547 M)(0.0821 Latm/molK)(298 K) = ~~**41.82 atm**~~

20. What would be the change in osmotic pressure if the same number of moles of sugar instead of salt were dissolved in the water?

Answer: i would be half has large, so the change in osmotic pressure would be half as large. Thus, π = 41.82 atm/2 = ~~**20.91 atm.**~~