CH 302 Spring 2007 Worksheet 4
Practice Exam 1

1. Predict the signs of ΔH and ΔS for the sublimation of CO_2.
   a. $\Delta H > 0, \Delta S > 0$
   b. $\Delta H > 0, \Delta S < 0$
   c. $\Delta H < 0, \Delta S > 0$
   d. $\Delta H < 0, \Delta S < 0$

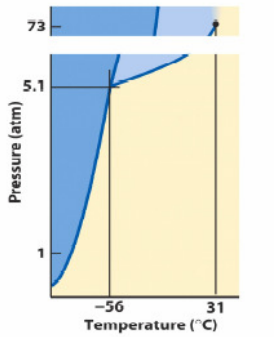
   Answer: This reaction happens only at higher temperatures, which means $\Delta H > 0$ and $\Delta S > 0$.

2. Vapor pressure increases _____ with temperature.
   a. Linearly
   b. Exponentially
   c. Logarithmically
   d. Quadratically

   Answer: Recall the Clausius-Clapeyron equation. Pressure is related exponentially to temperature.

3. Which of the following salts will dissolve most easily in water?
   a. LiF
   b. MgO
   c. BN
   d. KBr

   Answer: The salt with the lowest charge density will dissolve the easiest. BN and MgO both have multiple charges, so they have high charge density. Li+ and F- are smaller than K+ and Br-, so LiF has a higher charge density than KBr.



4. For this question, refer to the phase diagram shown above. What is the phase of this substance at -56°C and 5.1 atm?
   a. Solid
   b. Liquid
   c. Gas
   d. Mixture of solid and gas
   e. Mixture of solid, liquid, and gas
   f. Supercritical fluid

   Answer: This is the triple point, which is the point at which solid, liquid, and gas are all at equilibrium with each other.

5. For this question, refer to the phase diagram shown above question 4. The substance is originally held in a container at -60°C and 20 atm. It is then heated to room temperature, and next allowed to expand to atmospheric pressure. What happens to the substance?
   a. The liquid in the container boils.
   b. The liquid in the container becomes a supercritical fluid.
   c. The gas in the container becomes a supercritical fluid.
   d. The solid in the container sublimes.
   e. The solid in the container melts, then the resulting liquid boils.
   f. The solid in the container sublimes, and then the resulting gas condenses.

   Answer: Just trace the two steps on the phase diagram.

6. 1 kg of water starts at 200°C and is allowed to cool to room temperature. 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?
   a. -2775 J
   b. -2775 kJ
   c. +2775 kJ
   d. -1745 kJ
   e. +1745 kJ

   Answer: Divide the process into three stages.

   Cool steam 200°C → 100°C:

   $\Delta H = mc_{steam}\Delta T = (1000g)(2.009\ J/g°C)(-100°C) = -201\ kJ$

   Condense steam:

   $\Delta H = m\Delta H_{melting} = -m\Delta H_{vaporization} = (1000\ g)(2.26\ kJ/g) = -2260\ kJ$

   Cool water 100°C → 25°C:

   $\Delta H = mc_{water}\Delta T = (1000g)(4.186\ J/g°C)(-75°C) = -314\ kJ$

   ΔH_{tot} = -201 kJ + -2260 kJ + -314 kJ = -2775 kJ

7. Which of the following gases will be most soluble in water?
   a. CH_4
   b. O_2
   c. CCl_4
   d. He
   e. Cl_2

   Answer: Since all of these are nonpolar, solubility in water can be ranked based on size. Smaller molecules can more easily fit between water molecules.

8. Rank the following in terms of increasing miscibility with water: CH_3OH, CH_4, CH_3CH_2OH, $CH_3CH_2CH_2OH$.
   a. $CH_3CH_2CH_2OH < CH_3CH_2OH < CH_3OH < CH_4$
   b. $CH_4 < CH_3OH < CH_3CH_2OH < CH_3CH_2CH_2OH$
   c. $CH4 < CH_3CH_2CH_2OH < CH_3CH_2OH < CH_3OH$
   d. $CH_3OH < CH_3CH_2OH < CH_3CH_2CH_2OH < CH_4$

   Answer: CH_4 is nonpolar, so it is not soluble in water. All of the alcohol (molecules with –OH) groups are polar, but the shorter the carbon backbone attached to the –OH, the soluble the molecule is in water.

9. You're cleaning your pet goldfish's tank, and you put him in a bowl containing pure water. Because the fish has a certain electrolyte balance inside its body that doesn't exist in the water, a concentration gradient is created. What is the name of the colligative property that explains why your fish blows up like a water balloon?
   a. Vapor pressure
   b. Freezing point depression
   c. Boiling point elevation
   d. Osmotic pressure
   e. Density depression
   f. Ion diffusion
   Answer: The concentration gradient causes osmotic pressure.

10. 25 g of acetic acid (CH_3COOH) and 75 g of ethanol (CH_3CH_2OH) are mixed together. At 25°C, the vapor pressures of these compounds are 16 and 59 torr, respectively. What is the vapor pressure of the mixture?
   a. 37.50 torr
   b. 48.25 torr
   c. 26.75 torr
   d. 50.25 torr
   e. 24.75 torr

   Answer: nacetic = 25g /(60 g/mol) = 0.417 mol
   nethanol = 75 g/(46 g/mol) = 1.63 mol
   $P_{acetic} = X_{acetic}P°_{acetic}$
   = (0.417 mol)/(0.417 mol + 1.63 mol) x 16 torr = 3.26 torr
   Similarly, $P_{ethanol}$ = 46.99 torr. So
   Ptotal = 3.26 torr + 46.99 torr = 50.25 torr

11. Butanol boils at 118°C and has a ΔH_{vap} of 50 kJ/mol. What is butanol's vapor pressure at room temperature, 25°C? Recall that 1 atm = 760 torr and R = 8.314 J/mol K.
   a. 6.28 torr
   b. 91965 torr
   c. 756.4 torr
   d. 763.7 torr

   Answer: Remember that the boiling point is the point at which the vapor pressure equals 1 atm.
   $\ln(P_1/P_2) = \Delta H/R\ (1/T_2 - 1/T_1)$
   $P_1 = P_2\exp[\Delta H/R(1/T_2 - 1/T_1)]$
   $P_1 = (760\text{ torr})\exp[(50000\text{ J/mol})/(8.314\text{ J/molK})(1/391\text{ K} - 1/391\text{ K})]$
   $P_1 = 6.28$ torr

12. 1 mol of each of the following is added to 1 L of water. Rank the solutions in terms of **increasing freezing point**. BaS, $CaCl_2$, sugar, LiCl.
   a. BaS < sugar < LiCl < $BaCl_2$
   b. $BaCl_2$ < LiCl < sugar < BaS
   c. sugar < BaS < LiCl < $BaCl_2$
   d. $BaCl_2$ < LiCl < BaS < sugar

   Answer: Remember that dissolved substances **decrease** the freezing point of the solvent. So $BaCl_2$ has the **lowest** (most depressed) freezing point, followed by LiCl, sugar (which doesn't dissociate), and BaS (which doesn't dissolve at all).

13. Which of these is **not** an example of using a colligative property to your advantage?
   a. Adding salt to water so that your spaghetti cooks faster.
   b. Mixing ethylene glycol and water in your radiator so that the liquid remains liquid over a wide range of temperatures.
   c. Cooking your spaghetti in a pressure cooker so that it cooks faster.
   d. Salting the roads after it snows.

Answer: Colligative properties are properties of solutions, where the solute affects a property of the solvent. A pressure cooker raises the boiling point, but is not a solution property.

14. 20 g of $BaCl_2$ is added to 1 L of water (d_{water} = 1 g/mL). What is the boiling point of the water, given the boiling point of pure water is 100°C and K_b for water is 0.512 °C/m?
   a. 99.852 °C
   b. 100.148°C
   c. 99.951°C
   d. 100.0492°C
   e. 89.760°C
   f. 110.240°C

Answer: n_{BaCl2} = 20 g / (208 mol/g) = 0.0962 mol
$m = n_{BaCl} / m_{H2O}$ = 0.0962 mol / (1 kg) = 0.0962 m
$\Delta T_b = i\ m\ K_b$ = 3(0.0962 m)(0.512°C/m) = 0.148°C
$T_b = T_b^\circ + \Delta T_b$ = 100.148°C

15. Which is the correct expression of K given the reaction

$$NaCl\ (aq) + AgNO_3\ (aq) \rightarrow NaNO_3\ (aq) + AgCl\ (s)$$

   a. $K = \frac{[NaNO_3][AgCl]}{[NaCl][AgNO_3]}$
   b. $K = \frac{[NaCl][AgNO_3]}{[NaNO_3][AgCl]}$
   c. $K = \frac{[NaNO_3]}{[NaCl][AgNO_3]}$

Answer: Remember that you don't consider solids when constructing an expression for K.

16. For the reaction below, 1 atm C_8H_{18} and 1 atm O_2 (and no CO_2 or H_2O) are mixed together. The equilibrium pressure of O_2 is 0.1 atm. What is K_p for this process?

$$2\ C_8H_{18}\ (g) + 25\ O_2\ (g) \leftrightarrow 16\ CO_2\ (g) + 18\ H_2O\ (g)$$

   a. 4.02
   b. 0.25
   c. 1.45×10^{-18}
   d. 6.92×10^{17}
   e. 2.78×10^{25}

Answer:

$2\ C_8H_{18}$ (g)	$25\ O_2$ (g)	$16\ CO_2$ (g)	$18\ H_2O$ (g)
1	1	0	0
-2x	-25x	+16x	+18x
1-2x	0.1	16x	18x

But $P_{O2,eq}$ = 0.1 = 1-25x, so x = 0.036 atm
So P_{C8H18} = 1-2(0.036) = 0.928 atm.
Similarly, P_{CO2} = 0.576 atm, P_{H2O} = 0.648 atm.
$K = (0.576)^{16}(0.648)^{18}/(0.928)^2(0.1)^{25} = 6.92 \times 10^{17}$

17. For some temperature, assume that K_p for the combustion reaction below is 10^5. You mix 1 atm each of C_2H_5OH, O_2, H_2O, and CO_2. Which of the following is a possible set of equilibrium concentrations?

$$C_2H_5OH\ (g) + 3\ O_2\ (g) \leftrightarrow 2\ CO_2\ (g) + 3\ H_2O\ (g)$$

a. $P_{C2H5O2} = 1.31$ atm, $P_{O2} = 1.92$ atm, $P_{CO2} = 0.390$ atm, $P_{H2O} = 0.0845$ atm
b. $P_{C2H5O2} = 0.0652$ atm, $P_{O2} = 0.691$ atm, $P_{CO2} = 1.94$ atm, $P_{H2O} = 1.62$ atm
c. $P_{C2H5O2} = 0.691$ atm, $P_{O2} = 0.0652$ atm, $P_{CO2} = 1.62$ atm, $P_{H2O} = 1.94$ atm
d. $P_{C2H5O2} = 1.92$ atm, $P_{O2} = 1.31$ atm, $P_{CO2} = 0.0845$ atm, $P_{H2O} = 0.390$ atm

Answer: Plug in and check. $(1.62)^2(1.94)^3/(0.691)(0.0652)^3 = 100{,}049 = \sim 10^5$

18. Calculate the equilibrium concentration of CO_2, given that you start with 1 M each of CO, CO_2, and H_2 in water, and $K_c = 223$.

$$CO\ (aq) + H_2O\ (l) \leftrightarrow CO_2\ (aq) + H_2\ (aq)$$

a. 1.98 M
b. 0.126 M
c. 0.00893 M
d. 1.87 M

Answer:

CO (aq)	H_2O (l)	CO_2 (aq)	H_2 (aq)
1	XXXXX	1	1
-x	XXXXX	+x	+x
1-x	XXXXX	1+x	1+x

$K = 223 = (1+x)^2/(1-x)$
$x^2 + 2x + 1 = 223 - 223x$
$x^2 + 225x - 222 = 0$
Solving the quadratic equation gives $x = 0.98$
$[CO_2] = 1 + 0.98 = 1.98$ M

19. For the formation of ammonia, imagine you start with 1.5 M N_2, 1 M H_2 and 2.5 M NH_3. Which way will the reaction shift, given $K_c = 3.8$?

$$N_2(g) + 3\ H_2(g) \leftrightarrow 2\ NH_3\ (g)$$

a. To the products.
b. To the reactants.
c. It won't.
d. Up.
e. Down.

Answer: $Q = (2.5)^2/(1.5)(1)^3 = 4.17 > K$, so the reaction shifts to the left.

20. An exothermic reaction is placed over a flame. What happens to the reaction?
a. Nothing happens.
b. The reaction shifts toward the reactants.
c. The reaction shifts toward the products.

Answer: Heat is added to the reaction, so it shifts to use up heat. It does this by shifting to the left, undergoing an endothermic reaction (since it's the reverse of an exothermic reaction).

21. The pressure on the vessel in which the following reaction is taking place is doubled. What happens to the reaction?

$$N_2\ (l) + O_2\ (g) \leftrightarrow 2\ NO\ (g)$$

a. Nothing happens.
b. The reaction shifts toward the reactants.
c. The reaction shifts toward the products.

Answer: The reaction shifts to decrease the pressure. Since there are fewer gas molecules on the left, the reaction shifts to the left to decrease the total amount of gas present.

22. At 298 K, ΔG for a given reaction is -25.7 kJ. What is K for this reaction at 298 K?
a. 1.01
b. 0.990
c. 3.20×10^{4}
d. 3.13×10^{-5}
e. 22.0

Answer: $K = \exp[-\Delta G/RT]$
$= \exp[-(-25700\ J)/(8.314\ J/molK \times 298\ K)] = 31986$

23. At some temperature, $K_w = 5 \times 10^{-14}$. What is the pOH of pure water at this temperature?
a. 6.00
b. 6.65
c. 7.00
d. 7.35
e. 8.00

Answer: For pure water, $[OH^-] = [H^+] = K_w^{1/2} = (5 \times 10^{-14})^{1/2} = 2.24 \times 10^{-7}$
$pOH = -\log[OH^-] = -\log[2.24 \times 10^{-7}] = 6.65$

24. Which of the following is the most likely temperature at which $K_w = 5 \times 10^{-14}$ as above, given $K_w = 1 \times 10^{-14}$ at room temperature?
a. 0 °C
b. 12 °C
c. 25 °C
d. 50 °C

Answer: Remember that K_w increases as the temperature increases. Thus, the given K_w must occur at a temperature greater than 25°C.

25. 1 mole of HNO_3 is added to 10 L of water. What is the pH of this solution?
a. 0
b. 1
c. 2
d. 7
e. 12
f. 13
g. 14

Answer: $[H^+] = Ca = 1\ mol/10\ L = 0.1\ M$
$pH = -\log[H^+] = 1$

26. The pK_a of hydrofluoric acid (HF) is 3.15. If 132 g of HF is dissolved in 1 L of water, what is the pOH of the resulting solution?

a. 13.5
b. 12.83
c. 14.66
d. 1.17
e. 14.82

Answer: $K_a = 10^{-3.15}$
$C_a = n_{HF}/V_{soln} = (132\ g / 20\ g/mol)/1\ L = 6.6\ M$
$[H+] = (KaCa)1/2 = (10\text{-}3.15 \times 6.6)^{1/2} = 0.0684$
$pH = -\log(0.0684) = 1.17$
$pOH = 14 - pH = 14 - 1.17 = 12.83$

27. 1 mole of ethylenediamine is dissolved in 1 L water, and the resulting $[OH^-]$ is 3.16×10^{-11} M. What is K_a for ethylenediamine?

a. 10^{-22}
b. 10^{-7}
c. 5×10^{-6}
d. 1.8×10^{-2}

Answer: $[H^+] = 10^{-14}/[OH^-] = 10^{-14}/(3.16 \times 10^{-11}) = 3.16 \times 10^{-4}$ M
$[H^+] = (K_aC_a)^{1/2}$
$K_a = [H^+]^2/C_a = (3.16 \times 10^{-4}\ M)^2/1\ M = 1.00 \times 10^{-7}$

28. Which of the following is **not** a strong acid?

a. HF
b. HCl
c. HBr
d. HI
e. $HClO_4$
f. $HClO_3$

Answer: Memorize the strong acids and bases.

29. What is the pH of a solution with $[OH^-] = 3.7 \times 10^{-4}$ M?

a. 2.7×10^{-11}
b. 3.43
c. 10.57
d. 11.43
e. 2.69
f. 12.54

Answer: $pOH = -\log(3.7 \times 10^{-4}) = 3.43$
$pH = 14 - pOH = 14 - 3.43 = 10.57$

30. Which of the following is the strongest base?

a. Ammonia, $K_b = 1.8 \times 10^{-5}$
b. Aniline, $K_b = 4.2 \times 10^{-10}$
c. Dimethylamine, $K_b = 5.1 \times 10^{-4}$
d. Pyridine, $K_b = 1.4 \times 10^{-9}$
e. Urea, $K_b = 1.5 \times 10^{-14}$

Answer: Larger K_a/K_b means stronger acid/base.