Chemistry 10123, **Exam 1** **Answer Key**
February 5, 2020

1. (8 points) **SHOW ALL WORK.** Concentrated hydrochloric acid, $HCl_{(aq)}$, has a density of 1.19 g/mL and is 37.0 % HCl by weight. Determine the ***molar concentration*** of HCl in the solution. (Formula masses: H_2O = 18.0 g/mole; HCl = 36.5 g/mole)

   (37.0 g) (1 mole HCl / 36.5 g) = 1.0137 mole HCl (in 100 g of solution)

   (100 g) (1 mL / 1.19 g) = 84.0 mL = 0.084 L

   M = (1.0137 mole HCl) / (0.084 L) = 12.1 M

2. (4 points) Consider the aqueous solutions labeled **A - E** as follows.

   A: pure H_2O **B**: 1.0 m HNO_2 **C**: 1.0 m KNO_2
   D: 1.0 m glucose, $C_6H_{12}O_6$ **E**: 1.0 m K_2SO_4

   Arrange these in order of increasing boiling point, lowest to highest.
   Write only the letters of the solutions in the blanks below.

   A < D < B < C < E
   lowest bp highest bp

3. (2 points) (a) The conjugate base of $H_2PO_4^-$ is HPO_4^{2-}.
   (b) $P_2H_5^+$ is the conjugate acid of P_2H_4.

4. (2 points) ***Circle*** any of the following common substances that are colloidal dispersions.

   fog sand table salt milk antifreeze Jell-O

5. (2 points) The vapor pressure of water is 23.8 torr at 25 °C. If 2.0 moles of a non-volatile solute are dissolved in 8.0 moles of water at that temperature, the vapor pressure of the resulting solution should be 19.0 torr.

6. (7 points) **SHOW ALL WORK.** For the following reaction, K_c = 64. A quantity of HI is placed in an empty container and the system is allowed to reach equilibrium. At that point, the ***total pressure*** in the container is found to be 3.00 atm. Calculate the partial pressure of H_2 (in atm) at equilibrium.

	$H_{2(g)}$ +	$I_{2(g)}$ $\rightleftharpoons$	$2\ HI_{(g)}$
I	0	0	P_i
C	+ x	+ x	- 2x
E	x	x	P_i - 2x

let P_i = initial P_{HI}

$K_p = K_c$ because $\Delta n = 0$

$P_{total} = P_{HI} + P_{I2} + P_{H2}$ = 3.0 atm = x + x + (P_i - 2x) so P_i = 3.0 atm

$K_p = 64 = (3.0 - 2x)^2 / x^2$ so, $8 = (3.0 - 2x) / x$ ∴ P_{H2} = x = 0.30 atm

7. **SHOW ALL WORK.** Glycerol, $C_3H_5(OH)_3$ (92.0 g/mole) is a non-dissociating, non-volatile liquid that is very soluble in water. A certain aqueous solution of glycerol has a boiling point of 105.5 °C. Determine the quantities in parts (a) and (b) below, related to this solution.
[Some constants for H_2O (18.0 g/mole): K_b = 0.51 °C/m and K_f = 1.86 °C/m]

(a) (7 points) The freezing point of the solution in °C.

$\Delta t_b = K_b\, m$ so, m = 5.5 °C / 0.51 °C/m)

m = 10.78 mole Gly / kg of H_2O

$\Delta t_f = K_f\, m$ = (1.86 °C/m) (10.78 m) = 20.1 °C

∴ FP = - 20.1 °C

(b) (7 points) The weight percent of glycerol in the solution.

(10.78 mole Gly) (92 g/mole) = 992 g Gly (in 1 kg H_2O)

wt % = (992 g) / (992 g + 1,000 g) x 100 % = 49.8 %

8. (3 points) At a pressure of 380 torr, the solubility of O_2 gas in water is 6.50 x 10^{-4} M. If the pressure is increased to 25 atm, the solubility of O_2 should be 0.0325 M.

9. (4 points) The heat of solution ($\Delta H°_{soln}$) of an ionic compound in water is approximately equal to the sum of the lattice energy of the crystalline solid and the hydration energy of the ions in solution.

10. (7 points) **SHOW ALL WORK.** Using the data,

$2\, NO_{(g)} + Cl_{2(g)} \rightleftharpoons 2\, NOCl_{(g)}$ K_{c1} = 3.20 x 10^{-3}

$NO_{2(g)} \rightleftharpoons NO_{(g)} + 1/2\, O_{2(g)}$ K_{c2} = 3.95

determine the value of K_c for the following reaction.

$NOCl_{(g)} + 1/2\, O_{2(g)} \rightleftharpoons NO_{2(g)} + 1/2\, Cl_{2(g)}$

reverse first equation and divide by 2

reverse second equation, then add the equations

$K_c = 1 / [(K_{c1})^{1/2} (K_{c2})] = 1 / [(3.2 \times 10^{-3})^{1/2} (3.95)]$

K_c = 4.48

11. In a lab experiment, you are given two aqueous solutions labeled **A** and **B** as follows and asked to determine the molar concentration of H_2SO_4 in Solution **B**.

Solution **A**: NaOH, M = 0.250 Solution **B**: H_2SO_4, M = ???

(a) (3 points) Write a balanced, ***net ionic equation*** for the reaction that occurs when these two solutions are mixed together.

$$H^+ + OH^- \longrightarrow H_2O$$

(b) (10 points) **SHOW ALL WORK.** After carefully mixing 100 mL of solution **A** with 100 mL of solution **B**, you determine that the resulting solution has a pH of 12.63 at 25 °C. Calculate the molar concentration of the original H_2SO_4 solution (**B**).

moles OH^- initially = (0.10 L) (0.25 mole/L) = 0.0250 moles

pOH = 14.00 - pH = 1.37 so, $[OH^-]$ = $10^{-1.37}$ = 0.04266 M

moles OH^- in final solution = (0.04266 mole/L) (0.20 L) = 0.008532 moles

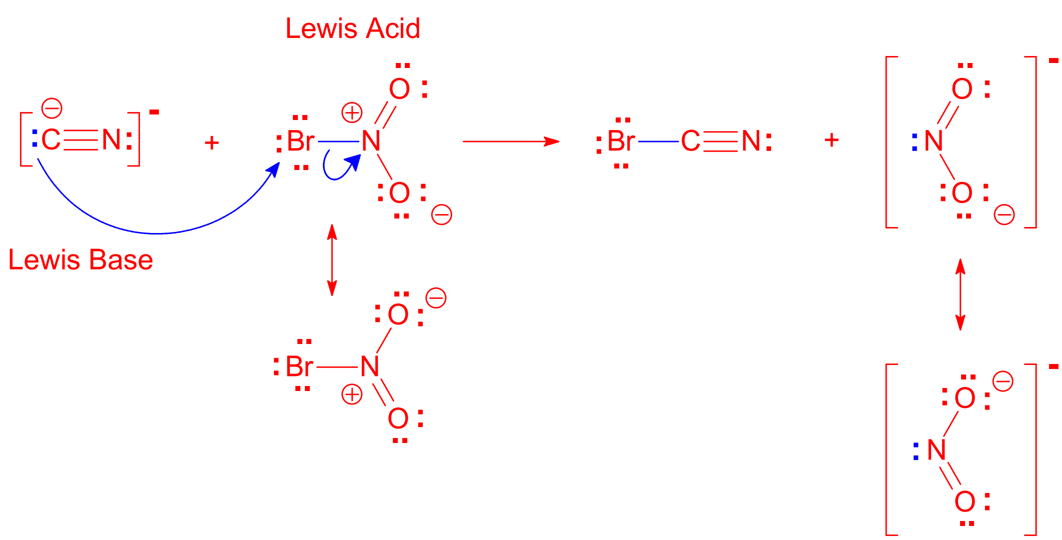
moles H^+ initial = moles OH^- neutralized = 0.0250 - 0.008532 = 0.01647 moles

molarity of H_2SO_4 = (0.01647 mole H^+) (1 mole H_2SO_4 / 2 mole H^+) / (0.10 L)

= 0.0823 M

12. (12 points) Consider the following reaction from the viewpoint of the Lewis acid-base concept. Write ***Lewis electron dot formulas*** (including formal charges and/or resonance forms if needed) for all four species in this reaction. *Clearly indicate which reactant is the Lewis acid and which is the Lewis base.* Use arrow(s) to illustrate the formation and/or breaking of any chemical bond(s) during the reaction.

$$CN^- + BrNO_2 \rightleftharpoons BrCN + NO_2^-$$



13. A 3.00 g sample of solid $NH_2CO_2NH_{4(s)}$ (78.1 g/mole) was placed in an *empty* 1.00-L container and heated to 400 K until the following equilibrium is established. The mass of solid $NH_2CO_2NH_{4(s)}$ remaining at equilibrium was found to be 1.75 g.
[From other experiments, the reaction is known to be endothermic with ΔH° = 665 kJ.]

$$NH_2CO_2NH_{4(s)} \rightleftharpoons 2\ NH_{3(g)} + CO_{2(g)}$$

(a) (5 points) How will the equilibrium amount of $CO_{2(g)}$ be affected by each of following changes? Indicate your answer by writing the appropriate letter.

[**I** = increase, **D** = decrease, **N** = no change]

Change	**moles $CO_{2(g)}$**
add some $NH_{3(g)}$	D
add a catalyst	N
decrease the volume	D
remove some $NH_2CO_2NH_{4(s)}$	N
increase the temperature	I

(b) (2 points) If the temperature of the above equilibrium system is reduced, the actual value of K_c should (circle one): increase decrease stay the same

(c) (8 points) **SHOW ALL WORK.** Determine the equilibrium constant (K_c) at 400 K for this reaction using the data provided above.

moles $NH_2CO_2NH_4$ consumed = (3.00 g - 1.75 g) (1 mole / 78.1 g)
= 0.0160 mole

based on the 1:2:1 reaction stoichiometry:

moles CO_2 produced = moles $NH_2CO_2NH_4$ consumed = 0.0160 moles

moles NH_3 produced = 2 moles CO_2 = 2 (0.0160 moles)
= 0.0320 mole

$K_c = [NH_3]^2 [CO_2] = (0.0320)^2 (0.0160) = 1.64 \times 10^{-5}$

14. (7 points) **SHOW ALL WORK.** At 50 °C the value of K_w is 5.6×10^{-14}. Determine the pH of a solution made by dissolving 1.50 g of $Ba(OH)_2$ (171 g/mole) in enough water to make 500 ml of solution at this temperature.

moles OH^- = (1.50 g) (1 mole $Ba(OH)_2$ / 171 g) [2 mole OH^- / mole $Ba(OH)_2$]

= 0.0175 mole

$[OH^-]$ = (0.0175 mole) / (0.50 L) = 0.0351 M

$[H^+] = K_w / [OH^-] = (5.6 \times 10^{-14}) / (0.0351) = 1.60 \times 10^{-12}$

$pH = -\log [H^+] = -\log (1.60 \times 10^{-12}) = 11.80$