UNITS 4 AND 5: EQUILIBRIUM THEORY & APPLICATIONS

1. Consider the equilibrium: $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$ $\Delta H = -242$ kJ

   What would happen to the equilibrium concentrations of each of the substances when the following changes are made?

   a) increasing $[H_2O]$ $[H_2]\uparrow$ $[O_2]\uparrow$ $[H_2O]_{net}\uparrow$slightly

   b) increasing the temperature $[H_2]\uparrow$ $[O_2]\uparrow$ $[H_2O]_{net}\downarrow$

   c) increasing the volume of the container $[H_2]_{net}\downarrow$slightly $[O_2]_{net}\downarrow$slightly $[H_2O]_{net}\downarrow$

   d) increasing the pressure $[H_2]_{net}\uparrow$slightly $[O_2]_{net}\uparrow$slightly $[H_2O]_{net}\uparrow$

2. Consider the equilibrium: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2\,NH_{3(g)}$ $\Delta H = -92$ kJ

   What conditions will increase the equilibrium concentration of ammonia? $\downarrow$T, $\uparrow$P, $\uparrow$ either reactant [ ]

3. Describe the 5 characteristics of a reaction system that is at equilibrium.

Frome ET01: The system is closed. The forward reaction rate equals the reverse reaction rate. The concentration of the reactants and products are constant.. The temperature and pressure remain constant. The same equilibrium state can be reached by starting with reactant or products.

4. Consider the equilibrium: $A_{(g)} + 2B_{(g)} \rightleftharpoons C_{(g)} + D_{(g)}$ + energy

   What affect (if any) do the following changes have on the concentrations of A, B, C and D?

   a) increase [D] $[A]_{net}\uparrow$, $[B]_{net}\uparrow$, $[C]_{net}\downarrow$, $[D]_{net}\uparrow$slightly

   b) decrease temperature $[A]_{net}\downarrow$, $[B]_{net}\downarrow$, $[C]_{net}\uparrow$, $[D]_{net}\uparrow$

   c) decrease volume (increase pressure) $[A]_{net}\uparrow$slightly, $[B]_{net}\uparrow$slightly, $[C]_{net}\uparrow$, $[D]_{net}\uparrow$

5. Consider the equilibrium: $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ $K = 0.129$

   At equilibrium, $[PCl_5] = 0.235$ mol/L and $[PCl_3] = 0.174$ mol/L. Calculate the concentration of chlorine at equilibrium.

   0.174 mol/L

   K_{eq}= [Products][Reactants] =$[PCl3]_{[Cl2]}[PCl5]$

   $0.129=[0.174mol/L]_{[Cl2]}[0.235mol/L]$

   $[Cl2]=0.17422mol/L$

6. Consider the equilibrium: $2\ NH_{3\,(g)} \rightleftharpoons N_{2\,(g)} + 3H_{2\,(g)}$

When 15 g of ammonia is placed in a 5.0 L container and equilibrium is established, the concentration of nitrogen is determined to be 0.070 mol/L.

a) Calculate the initial concentration of ammonia. 0.176 mol/L (0.18 mol/L sig fig)

b) Calculate the equilibrium constant (K) value. 0.50 (0.41 if 0.18 mol/L was used)

7. What anion can be used to separate $Li^{+}_{(aq)}$ from $Pb^{2+}_{(aq)}$? Any of: $Cl^-/Br^-/I^-/ SO_4^{2-}/OH^-/PO_4^{3-}/CO_3^{2-}$

8. The solubility of $Mg(OH)_2$ is 9.12×10^{-3} g/L. Calculate the solubility product (Ksp) value. 1.52×10^{-11} Hint: You must calculate molarity in mol/L

9. If 19.6 g of $BaI_{2\,(s)}$ is dissolved in 2.5 L of a 3.0×10^{-11} $CuNO_{3\,(aq)}$ solution, will a precipitate form? ($K_{sp}(CuI) = 1.1 \times 10^{-12}$)
$Q = 1.2 \times 10^{-12}$ since $Q > K_{sp}$ a precipitate forms Hint: You must create the ionic equation for CuI and look at the number of moles required to create the precipitate

10. The Ksp value for barium sulfate is 1.5×10^{-9}. Calculate the maximum mass of $BaSO_{4\,(s)}$ that will fully dissolve in 3.0 L of water. 2.8×10^{-2} g

11. a) Calculate the hydronium and hydroxide concentrations in a solution made by dissolving 4.00 g of NaOH in 10.0 L of water. $[H_3O^+] = 1.00 \times 10^{-12}$ mol/L and $[OH^-] = 0.0100$ mol/L

b) What is the pH and pOH of the solution? pOH = 2.000 and pH = 12.000

12. Calculate the hydronium and hydroxide concentrations in a solution made mixing 60.0 mL of 0.400 mol/L HCl and 50.0 mL of 0.400 mol/L NaOH. $[H_3O^+] = 0.0363$ mol/L and $[OH^-] = 2.15 \times 10^{-13}$ mol/L

13. What is the hydronium and hydroxide concentration of pure water at 10°C
$K_w = 2.95 \times 10^{-15}$ at 10°C $[H_3O^+] = [OH^-] = 5.43 \times 10^{-8}$ mol/L

14. If 20.0 mL of 0.050 mol/L $HCl_{(aq)}$ is required to neutralize 80.0 mL of $NaOH_{(aq)}$, determine the concentration of the base. $[NaOH] = 1.25 \times 10^{-2}$ mol/L

15. In a titration, 1.60 g of an unknown acid "HX" is dissolved in 50.0 mL water and titrated with base. If 70.0 mL of 0.200 mol/L NaOH is required to reach the endpoint, calculate the molar mass of HX. M = 114 g/mol

16. What is the percentage by mass (% m/m) of acetic acid (ethanoic acid; CH_3COOH) in a sample of vinegar if 45.00 mL of 0.500 mol/L NaOH is required to titrate a 25.00 mL sample of the vinegar to the phenolphthalein endpoint.
$D_{vinegar} = 1.06$ g/mL % m/m = 5.09%

17. A 0.020 mol/L solution of a weak acid "HA" has a pH of 2.80. Find the K_a of the acid. $K_a = 1.3 \times 10^{-4}$

18. Given benzoic acid has a $K_a = 7.0 \times 10^{-5}$, calculate the $[H_3O^+]$ for a 0.0085 mol/L solution of this weak acid. $[H_3O^+] = 7.7 \times 10^{-4}$ mol/L

19. A 1.0 L solution is prepared by dissolving 0.20 mol HF and 1.0 mol KF.

a) Write the Bronsted-Lowry acid-base equation of HF reacting with water and write the K_a equation.

$HF_{(aq)} + H_2O_{(l)} \quad F^-_{(aq)} + H_3O^+_{(aq)}$

Ka=F-H3O+HF

b) Create an ICE table. Assume that KF dissociates 100%.

$HF_{(aq)} + H_2O_{(l)} \quad F^-_{(aq)} + H_3O^+_{(aq)}$

	HF	H_2O	F^-	H_3O^+
[I]	0.20	-	1.0	0
[C]	- x	-	+x	+x
[E]	0.20 - x	-	1.0 + x	x

c) Calculate the $[H_3O^+]$ and pH of the solution. $K_a = 6.67 \times 10^{-4}$ $[H_3O^+] = 1.3 \times 10^{-4}$ mol/L; pH = 3.87

20. Methylamine (aminomethane) is a weak base with $K_b = 4.37 \times 10^{-4}$.

a) Write the Bronsted-Lowry acid-base equation for CH_3NH_2 reacting with water.

$CH_3NH_{2(aq)} + H_2O_{(l)} \quad CH_3NH_3^+{}_{(aq)} + OH^-_{(aq)}$

b) If a 10.0 L solution of methylamine is found to have a pH of 12.00, calculate the mass of CH_3NH_2 that was dissolved to produce the solution. $m_{CH3NH2} = 74.2$ g