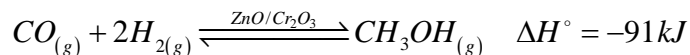
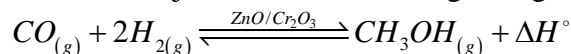


In Class Exercise for Chapter 13 - 14

1. Methanol (CH_3OH) is manufactured in the presence of a $\text{ZnO}/\text{Cr}_2\text{O}_3$ catalyst through the following equation:

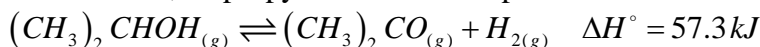


Does the amount of methanol increase, decrease, or remain the same when an equilibrium mixture of the above reaction is subjected to the following changes:

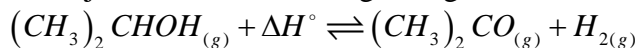


- (a) the temperature is increased – goes toward reactants, $[\text{CH}_3\text{OH}]$ decreases
- (b) the volume is decreased – more gaseous moles on reactant side, goes toward products, $[\text{CH}_3\text{OH}]$ increases
- (c) helium is added – not involved in the eq so no change in $[\text{CH}_3\text{OH}]$
- (d) CO is added – goes toward products, $[\text{CH}_3\text{OH}]$ increases
- (e) hydrogen is removed – goes toward reactants, $[\text{CH}_3\text{OH}]$ decreases

2. In the gas phase at 400°C , isopropyl alcohol decomposes to acetone and H_2 gas by:



Does the amount of hydrogen gas increase, decrease, or remain the same when the equilibrium mixture is subjected to the following changes:



- (a) the temperature is increased – goes toward products, $[\text{H}_2]$ increases
- (b) the volume is increased – more gaseous moles on product side so goes toward product, $[\text{H}_2]$ increases
- (c) Ar is added – no change in $[\text{H}_2]$
- (d) Acetone is added – goes toward reactants, $[\text{H}_2]$ decreases
- (e) Isopropyl alcohol is added – goes toward products, $[\text{H}_2]$ increases

3. At a certain temperature, $K_p = 1.42$ for the reaction shown below. Calculate the equilibrium partial pressures and the total pressure if the initial partial pressures are $P_{\text{PCl}_5} = 3.00 \text{ atm}$, $P_{\text{PCl}_3} = 2.00 \text{ atm}$, $P_{\text{Cl}_2} = 1.50 \text{ atm}$.

	$\text{PCl}_{5(g)}$	$\text{PCl}_{3(g)}$	$\text{Cl}_{2(g)}$
Initial	3.00	2.00	1.50
Change	-x	+x	+x
Eq	3.00 - x	2.00+x	1.50+x

$$K_p = \frac{P_{PCl_3(g)} P_{Cl_2(g)}}{P_{PCl_5(g)}} = 1.42 = \frac{(2.00+x)(1.50+x)}{(3.00-x)} \rightarrow x^2 + 4.92x - 1.26 = 0 \rightarrow x = \frac{-4.92 \pm \sqrt{(4.92)^2 - 4(1)(-1.26)}}{2(1)}$$

$$x = 0.244 \text{ atm or } x = -5.16 \text{ atm}$$

$$P_{PCl_5(g), eq} = 3.00 - x = 2.76 \text{ atm}; P_{PCl_3(g), eq} = 2.00 + x = 2.24 \text{ atm}; P_{Cl_2(g), eq} = 1.50 + x = 1.74 \text{ atm}; P_{Tot} = 6.74 \text{ atm}$$

4. Calculate the pH of solutions prepared by:

(a) dissolving 0.20 g of sodium hydroxide in water to give 100.0 mL solution

$$\left(0.20 \text{ g} \times \frac{1 \text{ mol NaOH}}{39.998 \text{ g}} \times \frac{1 \text{ mol OH}^-}{1 \text{ mol NaOH}} \right) / 0.1000 \text{ L} = 0.050 \text{ M}$$

$$pH = 14 + \log[OH^-] = 12.70$$

(b) dissolving 1.26 g of pure nitric acid in water to give 0.500 L solution

$$\left(1.26 \text{ g} \times \frac{1 \text{ mol HNO}_3}{63.018 \text{ g}} \times \frac{1 \text{ mol H}^+}{1 \text{ mol HNO}_3} \right) / 0.5000 \text{ L} = 0.040 \text{ M}$$

$$pH = -\log[H^+] = 1.40$$

(c) diluting 40.0 mL of 0.075 M Ba(OH)₂ to a volume of 300.0 mL

$$\left(40.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.075 \text{ mol Ba(OH)}_2}{1 \text{ L}} \times \frac{2 \text{ mol OH}^-}{1 \text{ mol Ba(OH)}_2} \right) / 0.3000 \text{ L} = 0.020 \text{ M}$$

$$pH = 14 + \log[OH^-] = 12.30$$

(d) mixing equal volume of 0.20 M HCl and 0.50 M HNO₃

$$\left(1 \text{ L} \times \frac{0.20 \text{ mol HCl}}{1 \text{ L}} \times \frac{1 \text{ mol H}^+}{1 \text{ mol HCl}} + 1 \text{ L} \times \frac{0.50 \text{ mol HNO}_3}{1 \text{ L}} \times \frac{1 \text{ mol H}^+}{1 \text{ mol HNO}_3} \right) / 2 \text{ L} = 0.35 \text{ M}$$

$$pH = -\log[H^+] = 0.46$$

5. Lactic acid (C₃H₆O₃), which occurs in sour milk and foods such as sauerkraut, is a weak monoprotic acid. The pH of 0.10 M solution of lactic acid is 2.43. What is the value of K_a for this acid?

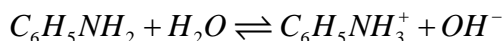


	HA	H ⁺	A ⁻
Initial	0.10	0	0
Change	-x	+x	+x
Eq	0.10 - x	+x	+x

$$pH = 2.43 \rightarrow [H^+] = 10^{-2.43} = 0.00372 \text{ M } H^+ = x$$

$$K_a = \frac{x^2}{0.10 - x} = \frac{(0.00372)^2}{0.10 - 0.00372} = 1.44 \times 10^{-4}$$

6. Aniline ($C_6H_5NH_2$) is an organic base used in the manufacture of dyes. Calculate the pH and concentrations of all species present in a 0.15 M solution of aniline ($K_b = 4.3 \times 10^{-10}$).



	$C_6H_5NH_2$	$C_6H_5NH_3^+$	OH^-
Initial	0.15	0	0
Change	-x	+x	+x
Eq	0.15 - x	+x	+x

$$K_b = \frac{x^2}{0.15 - x} = 4.3 \times 10^{-10} \text{ assume } x \ll 0.15 \rightarrow 4.3 \times 10^{-10} \sim \frac{x^2}{0.15}$$

$$x = 8.03 \times 10^{-6} M \text{ ck assumption: } \frac{8.03 \times 10^{-6}}{0.15} \times 100\% = 0.005\% < 5\%$$

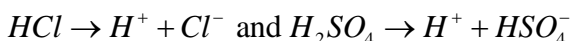
assumption is therefore valid

$$[C_6H_5NH_2] \sim 0.15 M; [C_6H_5NH_3^+] = [OH^-] = 8.03 \times 10^{-6} M$$

$$pH = 14 + \log [OH^-] = 8.90$$

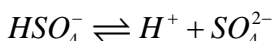
7. Calculate the pOH and the concentrations of all species in a solution prepared by mixing equal volumes of 0.2 M HCl and 0.6 M H_2SO_4 ($K_{a2} = 1.2 \times 10^{-2}$).

we have two strong acids which completely dissociate:



$$\text{Initially: } [H^+] = \frac{1 L \times 0.2 \frac{mol}{L} + 1 L \times 0.6 \frac{mol}{L}}{2L} = 0.4 \frac{mol}{L} \text{ and } [HSO_4^-] = \frac{1 L \times 0.6 \frac{mol}{L}}{2L} = 0.3 \frac{mol}{L}$$

since is a polyprotic acid we use the equation below to determine eq:



	HSO_4^-	H^+	SO_4^{2-}
Initial	0.30	0.4	0
Change	-x	+x	+x
Eq	0.30 - x	0.4+x	+x

$$K_a = \frac{[H^+][SO_4^{2-}]}{[HSO_4^-]} = \frac{x(0.4+x)}{0.3-x} = 1.2 \times 10^{-2} \rightarrow x^2 + 0.412x - 0.0036 = 0$$

$$x = \frac{-0.412 \pm \sqrt{0.412^2 - 4(1)(-0.0036)}}{2} \rightarrow x = 0.0085 M \text{ or } x = -0.420 M$$

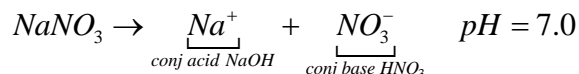
$$[HSO_4^-] = 0.3 - x = 0.291 M \rightarrow 0.3 M$$

$$[H^+] = 0.4 + x = 0.409 M \rightarrow 0.4 M$$

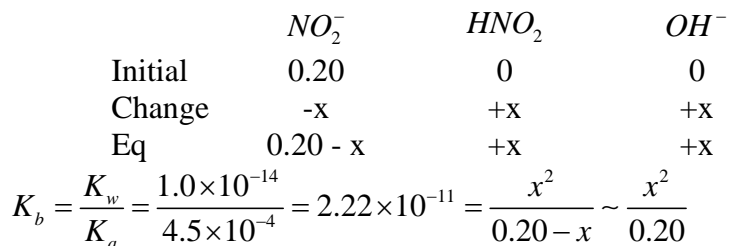
$$[SO_4^{2-}] = 0.009 M$$

$$pOH = 14 - pH = 14 + \log [H^+] = 13.60$$

8. Calculate the pH of 0.020 M solution of NaNO_3 (K_a is super huge). What about the pH of a 0.020 M NaNO_2 solution (4.5×10^{-4})?



$\text{NaNO}_2 \rightarrow \text{Na}^+ + \text{NO}_2^-$ in water we get $\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-$



$$x = 2.11 \times 10^{-6} \text{ M} \quad \text{ck assumption: } \frac{2.11 \times 10^{-6}}{0.2} \times 100\% = 0.001\% < 5\%$$

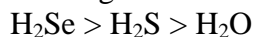
$$\text{pH} = 14 + \log[\text{OH}^-] = 8.32$$

9. Follow the directions given below and for each case explain your reasoning.

(a) arrange each group of compounds in order of decreasing acid strength

(i) H_2O , H_2S , H_2Se

As we go down a column we increase polarizability and reduce EN



(ii) HClO_3 , HClO , HClO_2

Acidity increases with # of O-atoms: $\text{HClO}_3 > \text{HClO}_2 > \text{HClO}$

(iii) PH_3 , H_2S , HCl

Across a row from left to right we increase EN – make sure we have an acid: $\text{HCl} > \text{H}_2\text{S} > \text{PH}_3$

(b) identify the weakest acid for each set below.

(i) $\boxed{\text{H}_2\text{SO}_3}$, HClO_3 , HClO_4 the strongest acid is HClO_4 since it has both the most EN central atom as well as the largest number of O-atoms; since Cl is more EN than S, HClO_3 is a stronger acid than H_2SO_3

(ii) $\boxed{\text{NH}_3}$, H_2O , H_2S EN decreases going across a row from right to left

(iii) $\text{B}(\text{OH})_3$, $\text{Al}(\text{OH})_3$, $\boxed{\text{Ga}(\text{OH})_3}$ for an oxoacid, acid strength decreases with decreasing EN of the central atom – since Ga is the least EN $\text{Ga}(\text{OH})_3$ is the weakest acid

(c) Identify the stronger base in each of the following pairs.

(i) $\boxed{\text{ClO}_2^-}$ vs. ClO_3^-

(ii) $\boxed{\text{HSO}_4^-}$ vs. HSeO_4^-

(iii) HS^- vs. $\boxed{\text{OH}^-}$

(iv) $\boxed{\text{HS}^-}$ vs. Br^-

10. If the percent dissociation of a 0.1 M solution of HNO_3 is actually 99.6%, what is the K_a for this acid?

$$\% \text{ dissociation} = \frac{[H^+]}{[HNO_3]} \times 100\% \rightarrow 0.996 = \frac{x^2}{0.1} \rightarrow x = 0.0996M$$

$$K_a = \frac{x^2}{0.1-x} = \frac{0.0996^2}{0.1-0.0996} = 28$$