1) To make nitric acid (HNO_3), in industry, the following process is used:

$$\_\_\_\_NH_{3(g)} + \_\_\_\_O_{2(g)} \longrightarrow \_\_\_\_NO_{(g)} + \_\_\_\_ H_2O_{(g)} \quad (a)$$

$$\_\_\_\_NO_{(g)} + \_\_\_\_O_{2(g)} \rightleftharpoons \_\_\_\_NO_{2\,(g)} \quad \Delta H > 0 \quad (b)$$

$$\_\_\_\_NO_{2(g)} + \_\_\_\_ H_2O_{(l)} \longrightarrow \_\_\_\_HNO_{3(aq)} + \_\_\_\_\_NO_{(g)} \quad (c)$$

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a) (3 pts) Balance each of the equations.

b) (1 pt) Would the equilibrium in reaction (b) be shifted to the right by raising or lowering the temperature?

c) (1 pt) Write the expression for the equilibrium constant of reaction (b).

d) (1 pt) How are the rates of product formation and reactant formation related to one another at equilibrium in reaction (b)?

e) (3 pts) If 3.0×10^3 kg of NH_3 are used what is the maximum amount of nitric acid (HNO_3) that could be made (assuming that the equilibrium (b) could be shifted all the way to the right.)

2) Consider the following equilibrium reached upon addition of 1.0 moles of $Fe(OH)_{2(s)}$ to 1.0 L of water:

$$Fe(OH)_{2(s)} \rightleftharpoons Fe^{+2}_{(aq)} + 2OH^-_{(aq)}$$

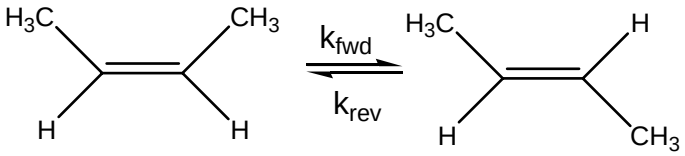
$K_{eq} = K_{sp} = 4.8 \times 10^{-17}$

a) Predict whether $Fe(OH)_2$ will dissolve, precipitate, or do neither after:

(a) water is added
(b) $Fe(OH)_2$ is added
(c) Solid $Fe(NO_3)_2$ is added
(d) Solid KNO_3 is added

b) Write the equilibrium expression for the equation:

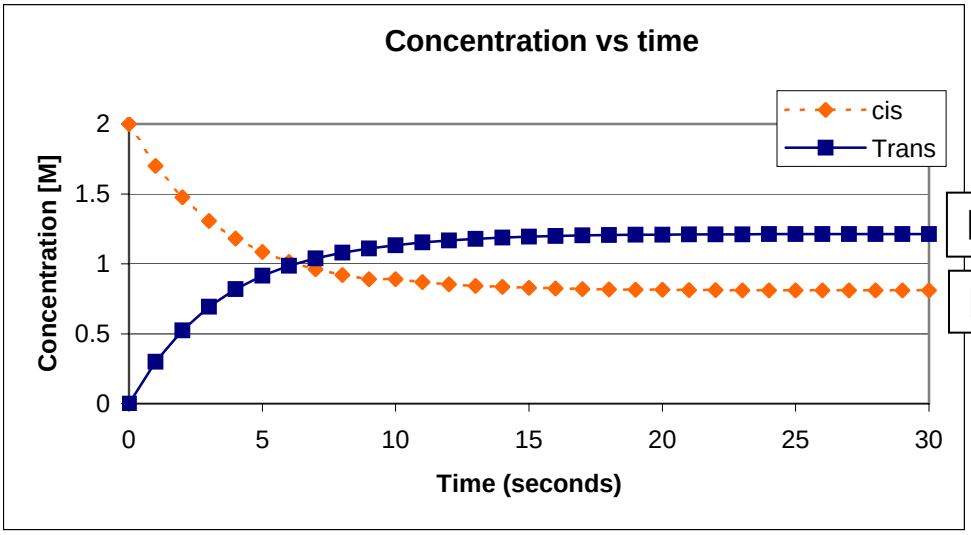
3) Equilibrium



cis-butene trans-butene

a) Write out the expression for K_{eq}:

a)



[trans] = 1.2 M

[cis] = 0.80 M

b) What is the value of K_{eq}:

c) Fill in the boxes below with <, >, or =.

At 0 seconds, Q ☐ K_{eq}

At 30 seconds Q ☐ K_{eq}

At 0 seconds k_{fwd} ☐ k_{rev}

At 30 seconds k_{fwd} ☐ k_{rev}

d) At 31 seconds, ½ of the trans-butene is removed. Immediately

Q becomes ☐ K_{eq}

k_{fwd} becomes ☐ k_{rev}

(*Fill in the boxes below with <, >, or =.)*

What are the concentrations of cis-butene and trans-butene when equilibrium is reached again?

cis-butene ☐ trans-butene ☐

4) The value of K_c for the reaction $A \rightleftharpoons B$ is 1.4×10^{15}.

At equilibrium:

A. The amount of A is slightly less than the amount of B.
B. The amount of A is much larger than the amount of B.
C. The amount of A is much less than the amount of B.
D. The amount of A is very close to the amount of B.
E. More information is needed to make any statement about the relative amounts of A and B.

5) Which of the following is a conjugate acid-base pair?

a. CH_3COO^- and H_2O
b. H_3O^+ and OH^-
c. CH_3COOH and CH_3COO^-
d. CH_3COOH and H_3O^+
e. CH_3COOH and OH^-

6) Phenolphthalein is an acid-base indicator that is colorless in its acid form and pink in its basic form, changing at pH = 8.5. Bromcresol green is yellow in its acidic form and blue in its basic form, changing at pH = 4.8. A solution is colorless in phenolphthalein and blue in bromcresol green. Therefore we can conclude that the pH of the solution is _____.

a. exactly 7.0
b. greater than 8.5
c. between 7.0 and 8.5
d. between 4.8 and 8.5
e. less than 4.8

7) Which compound contains the least acidic hydrogen/s?

a. GeH_4
b. H_2Se
c. HBr
d. AsH_3
e. More information is needed to answer this question.

8) Which combination of solutions is the best choice for making a buffer solution?

a. equal volumes of 1 M acetic acid and 0.005 M sodium acetate
b. equal volumes of 0.5 M nitric acid and 0.5 M sodium hydroxide
c. equal volumes of 0.1 M formic acid and 0.1 M sodium formate
d. equal volumes of 0.1 M sulfuric acid and 0.001 M sodium sulfate
e. equal volumes of 0.05 M hydrochloric acid and 0.075 ammonium chloride

9) Consider the salt calcium fluoride CaF_2 as a source of fluoride for drinking water which also provides the added bonus of calcium to build strong bonds and teeth.

Set up your ICE tables as you would normally. Then assume that you can cancel out x when necessary to avoid having to use the quadratic equation.

K_{sp} $CaF_2 = 3.9 \times 10^{-11}$
K_{sp} $Ca(OH)_2 = 7.9 \times 10^{-6}$
K_a HF = 7.2×10^{-4}

a) (4 points) The ADA (American Dental Association) recommends approximately 1 ppm F^- (mg/L). Considering only the solubility of CaF_2, is it soluble enough to provide 1 ppm fluoride? If yes, how much CaF_2 would you add per liter of water to achieve a concentration of 1 ppm?

c) Many areas of the country have hard water containing calcium and magnesium ions. Describe qualitatively how an existing of concentration of 100 mg/L calcium in hard water would affect the solubility of CaF_2. Describe quantitatively if 1ppm F^- could be obtained?

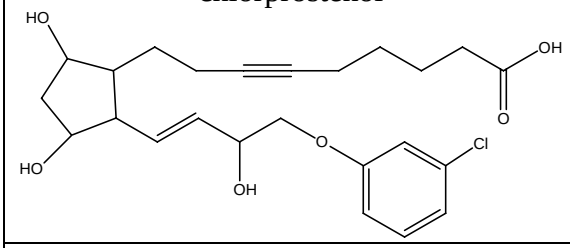
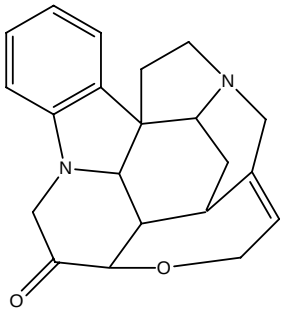
d) Assume that CaF_2 is completely soluble. What is the pH of the water when 1g of CaF_2 is dissolved in 1 liter of pure water?

e) Describe qualitatively how raising the pH of neutral water to 9 would affect the solubility of CaF_2 in solution (consider both the acid/base relationship and the solubility of $Ca(OH)_2$)

Acid/base relationship.

$Ca(OH)_2$ solubility

10) Fill in the following table using one of the choices from the top row to fill in each column

	Arrhenius or Bronsted acid OR base OR neutral in water	If acid or base, is it weakly dissociating or strongly dissociating	If acid or base is it mono, di, tri, etc. protic?
$HClO_4$			
NaCN			
CsI			
H_3AsO_4			
$H_2NCH_2CH_2NH_2$			
CH_3CH_2OH			
chlorprostenol 			
 strychnine			

11) Consider the gas-phase equilibrium A ⇌ B. In a series of experiments, different initial amounts of A and B are mixed together, and the mixture in each case is allowed to come to equilibrium. Which one of these experiments would yield values for the amounts of A and B present at equilibrium different from all the other experiments?

a. 3.0 moles A, 4.5 moles B
b. 4.5 moles A, 3.0 moles B
c. 1.5 moles A, 4.5 moles B
d. 7.5 moles A, no B
e. 0.5 moles A, 7.0 moles B

1)

12) A weak acid is 5% ionized at equilibrium. Therefore we can say that the ionization reaction is

_____-favored, because _____.

a. product; the amount of products << the amount of reactants
b. reactant; the amount of products << the amount of reactants
c. reactant; the amount of products >> the amount of reactants
d. product; the amount of products >> the amount of reactants
e. neither; not enough information is available to reach a conclusion

2)

13) Consider the gas-phase equilibrium A ⇌ B. Certain amounts of A and B are mixed in a vessel. As they come to equilibrium

a. the forward reaction rate declines and the reverse reaction rate rises.
b. the reverse reaction rate declines and the forward reaction rate rises.
c. both forward and reverse reaction rates decline.
d. both forward and reverse reaction rates rise.
e. either a. or b. above, but we cannot say which without more information.

3)

14) Once the reaction quotient, Q, has been determined for a reaction mixture, comparison with the value of the equilibrium constant, K, will determine

a. if the mixture is at equilibrium or not.
b. if the mixture has an excess of either products or reactants compared to equilibrium.
c. if the mixture will react to the left, to the right, or not at all.
d. Both a and b.
e. All of a, b, and c.

4)

15) Which reaction illustrates water acting as a base?

a. $Cu(H_2O)_4^{2+} + 4\,NH_3 \rightarrow Cu(NH_3)_4^{2+}\ 4\,H_2O$
b. $H_2CO_3 \rightarrow H_2O + CO_2$
c. $NH_3 + H_2O \rightarrow NH_4^{+} + OH^{-}$
d. $HPO_4^{-2} + H_2O \rightarrow OH^{-} + H_3PO_4$
e. $HSO_4^{-} + H_2O \rightarrow H_3O^{+} + SO_4^{2-}$

5)

16) For the reaction $2A \rightleftharpoons 3B$ $K_C = 1.37$

If the concentrations of A and B are equal at equilibrium, what is the value of that concentration?

1

17) (*7 points*) Given the equilibrium:

$$HCN_{(aq)} + H_2O_{(l)} \longleftrightarrow H_3O^+_{(aq)} + CN^-_{(aq)} \quad \Delta H > 0; \; K_a = 4.0 \times 10^{-10}$$

What happens to the concentration of hydrogen cyanide [HCN] when the following stresses are placed on the system at equilibrium? (*Circle the correct description of the [HCN] as a result of the stress described*)

	[HCN]		
a) Temperature is raised	increases	decreases	stays the same
b) NaCl is added	increases	decreases	stays the same
c) NaOH is added	increases	decreases	stays the same
d) NaCN is added	increases	decreases	stays the same
e) HCl is added	increases	decreases	stays the same
f) Water is added	increases	decreases	stays the same
g) The following are mixed together: 1×10^{-4} M HCN 1×10^{-4} M CN^- 5×10^{-3} M H_3O^+	increases	decreases	stays the same

7 (1 point each box)

18) (*2 points*) According to Chemical and Engineering News (July 4, 2005 p21), if current CO_2 emission trends continue, the oceans will become so acidic that corals will cease to thrive. The oceans are a sink for CO_2 from fossil fuels, absorbing about half of emissions. When CO_2 dissolves, it produces carbonic acid, which is corrosive to shells of marine organisms and can interfere with the oxygen supply of marine animals. In the past 200 years, the average pH of the surface seawater has declined from 8.3 to 8.2. What is the change in $[H_3O^+]$ that this corresponds to?

2

19) (*4 points*; *1/3 point per box*) *Fill in the following table*:

	Write out any and all equilibria taking place when this molecule is dissolved in water. If there is no equilibrium, then write NONE	Circle the approximate pH of the resulting solution
NH_4Cl		pH <7 pH~7 pH >7
NaCl		pH <7 pH~7 pH >7
HNO_3		pH <7 pH~7 pH >7
$Ca(OH)_2$		pH <7 pH~7 pH >7
$KClO_3$		pH <7 pH~7 pH >7
H_3PO_4		pH <7 pH~7 pH >7

20) (*9 points*) Consider the salt sodium fluoride used to fluorinate drinking water. At levels of 1 ppm used for fluorinated water, there is not enough fluoride to affect the pH. However, at high concentrations (1.0 M NaF), the salt does affect the pH. What is the pH of 1.0 M solution of NaF? (K_a HF = 7.2 x10^{-4})

a) Write out the relevant equilibrium equation that show the ion that affects the pH:

1

b) Label the acid, base, conjugate acid, and conjugate base in the equilibrium above. 1

c) What is the expression for the equilibrium constant of the equilibrium that you wrote in a?

1

d) What is the numerical value of the equilibrium constant?

1

e) What are the concentrations of all of the ions present in solution (Na^+, F^-, OH^-, H_3O^+) at equilibrium?

[Na^+] =	[F^-] =	[OH^-] =	[H_3O^+] =	4

f) What is the pH?

1

21) (*4 points*) Potassium hydrogen phthalate also known as KHP ($C_8H_5O_4K$) reacts with sodium hydroxide as shown below. KHP can be used to determine the concentration of a solution of sodium hydroxide through titration.

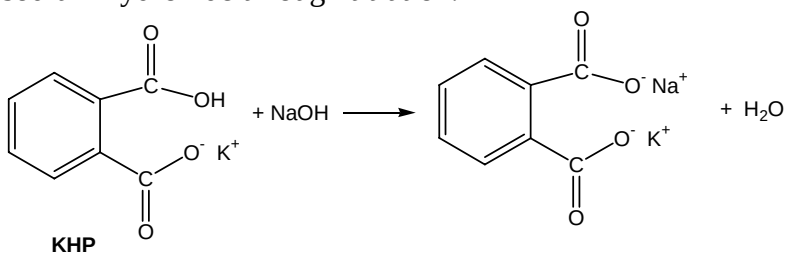


Table 1: Data from titrations

Weight KHP used (g)	Volume of NaOH used (mL)
0.7023	26.41
0.7321	26.89
0.7525	26.52

A titration is carried out by weighing dry KHP into a beaker, dissolving it in 75 mL of water, adding an indicator, and then titrating with NaOH until the endpoint is reached. The data obtained from three such titrations is recorded in Table 1.

a) What is the concentration of NaOH?

2

b) What indicator could you use in this titration? Describe how you would know when you had reached the end-point.

1

c) You can now use the NaOH solution to determine the concentration of acetic acid (CH_3COOH) in as 20.01 mL sample of vinegar. It takes 102.3 mL of the NaOH solution from part a to reach the end point. What is the molar concentration of acetic acid in vinegar?

1

22) (*4 points*) For the reaction

$H_{2(g)} + I_{2(g)} \longleftrightarrow 2\ HI_{(g)}$ $K_c = 50.0$ at 745K

a) Write out the expression for K_c

1

b) *Circle one*: The reaction at 745K is: reactant favored product favored 1

c) When 1.00 mol I_2 and 3.00 mol H_2 are allowed to come to equilibrium at 745 K in a flask of volume 10.00 L, what amount (in moles) of HI will be produced?

2

d) What amount of HI is present at equilibrium if an additional 3.00 mol H_2 is added to the 10.00 L flask?

2

23) (*2 points*) The K_{sp} of Ag_2SO_4 is 1.7 x10^{-5}. What is the maximum concentration of each of the ions that can be achieved by dissolving Ag_2SO_4 in water?

$[Ag^+]$ =	1	$[SO_4^{-2}]$ =	1