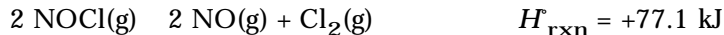


1. (8 points) *Le Chatelier's Principle* Consider the effect of various change on the following equilibrium.



Indicate in which direction the equilibrium shifts on making the changes below. (Answer *left*, *right*, or *no change*.)

Change**Direction of shift**

- (a) Increase in temperature _____
- (b) Increase initial NOCl concentration _____
- (c) Decrease volume of reaction vessel _____
- (d) Increase initial Cl₂ concentration _____

2. (6 points) K_c for the decomposition of ammonium hydrogen sulfide is 1.8×10^{-4} at 25 °C.



When the pure salt decomposes in a flask, what are the equilibrium concentrations of NH₃ and H₂S?

- (a) [NH₃] = 0.00018 M and [H₂S] = 0.00018 M
- (b) [NH₃] = 0.00036 M and [H₂S] = 0.00036 M
- (c) [NH₃] = 0.013 M and [H₂S] = 0.013 M
- (d) [NH₃] = 0.026 M and [H₂S] = 0.026 M
- (e) [NH₃] = 0.013 M and [H₂S] = 0.00018 M

NH₄HS is placed in a flask already containing 0.020 mol/L of NH₃ and then the system is allowed to come to equilibrium. What are the new equilibrium concentrations of NH₃ and H₂S?

- (a) [NH₃] = 0.020 M and [H₂S] = 0.020 M
- (b) [NH₃] = 0.027 M and [H₂S] = 0.0067 M
- (c) [NH₃] = 0.0067 M and [H₂S] = 0.027 M
- (d) [NH₃] = 0.033 M and [H₂S] = 0.013 M

3. (3 points) Barium sulfate, BaSO₄, is a poorly soluble salt. If you place some solid in 1.0 L of water, the barium ion concentration in the saturated solution will be

- (a) [Ba²⁺] = 1.1×10^{-10} M
- (b) [Ba²⁺] = 2.2×10^{-10} M
- (c) [Ba²⁺] = 1.1×10^{-5} M
- (d) [Ba²⁺] = 2.2×10^{-5} M
- (e) None of the above!?

4. (7 points) You have a flask containing a saturated solution of aluminum hydroxide, $\text{Al}(\text{OH})_3$. Is the pH of the solution *less than 7*, *equal to 7*, or *greater than 7*? _____

What is the approximate concentration of the aluminum ion in a saturated solution of aluminum hydroxide?

- (a) $2 \times 10^{-33} \text{ M}$
- (b) $4 \times 10^{-17} \text{ M}$
- (c) $3 \times 10^{-9} \text{ M}$
- (d) $1 \times 10^{-7} \text{ M}$

If you add some 1 M HCl to the saturated $\text{Al}(\text{OH})_3$ solution, will the concentration of Al^{3+} ion *increase*, *decrease*, or *stay the same*? _____

5. (6 points) If you place 15.0 mg of NiCO_3 (molar mass = 119 g/mol) in 1.0 L of pure water, will all of the compound dissolve before equilibrium is achieved, or does some of the compound remain undissolved?

- (a) All will dissolve.
- (b) Some will remain undissolved.

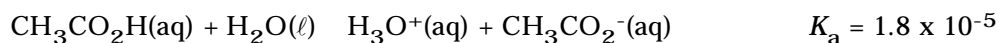
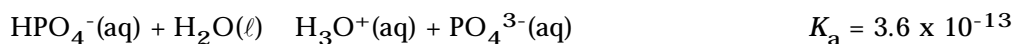
Prove your answer with an appropriate calculation. Show your work completely, carefully, and neatly!

10. (4 points) Write balanced chemical equations showing how the HPO_4^{2-} ion of sodium monohydrogen phosphate, Na_2HPO_4 , can be

(a) a Brønsted acid

(b) or a Brønsted base.

11. (8 points) Several acids are listed here with their respective equilibrium constants.



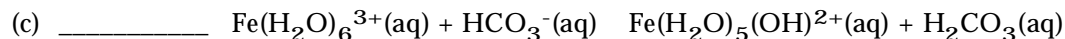
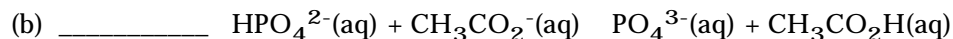
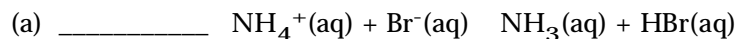
(a) Which is the strongest acid? _____

(b) What is the conjugate base of the acid HPO_4^{2-} ? _____

(c) Which acid has the weakest conjugate base? _____

(d) Which acid has the strongest conjugate base? _____

12. (6 points) For each reaction below, predict whether the equilibrium lies predominantly to the left or to the right.



13. (3 points) What is the pH of a 0.15 M solution of acetic acid?

(a) 2.78

(b) 11.22

(c) 1.41

(d) 5.57

(e) None of the above, heh!

14. (6 points) Calculate the concentration of OH^- and NH_4^+ and the pH of a 0.25 M solution of ammonia. *Show your work completely, carefully, and neatly!*

15. (3 points) A 0.015 M solution of an unknown acid has a pH of 2.67. What is the ionization constant, K_a , for the acid?

(a) $K_a = 2.9 \times 10^{-4}$

(b) $K_a = 3.6 \times 10^{-4}$

(c) $K_a = 1.4 \times 10^{-1}$

(d) $K_a = 1.6 \times 10^{-1}$

(e) None of the above, I think!

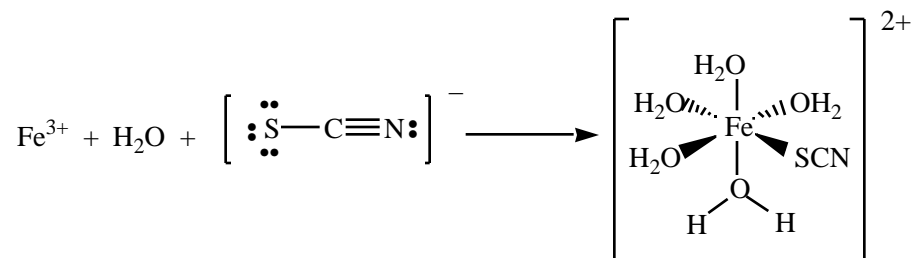
16. (9 points) Each of the salts below is dissolved in water to give a 0.1 M solution. Decide if each solution has a *pH less than 7, equal to 7, or greater than 7.*

Solution pH

- (a) NaCN _____
- (c) KBr _____
- (b) Na₃PO₄ _____
- (d) NH₄Cl _____
- (c) NaH₂PO₄ _____
- (e) FeCl₃ _____
- (f) LiNO₃ _____

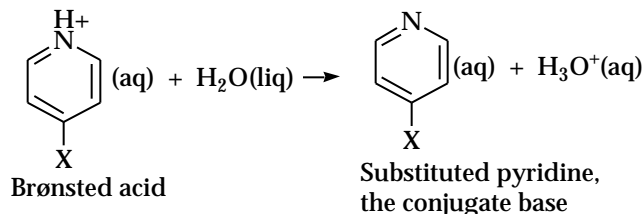
Which solution has the highest pH? _____ Which solution has the lowest pH?

17. (3 points) Lewis acids and bases. The way you detect the presence of iron(III) ion in your unknowns is to add thiocyanate ion, SCN⁻. The red complex ion that forms indicates the presence of the iron ion.



The reaction can be considered the reaction of a Lewis acid with a Lewis base. In this reaction which reactant or reactants are Lewis acids (there may be more than one) _____ and which reactant or reactants are Lewis bases (there may be more than one)?

18. (7 points) A hydrogen atom in the organic base pyridine, C_5H_5N , can be substituted by various atoms or groups to give XC_5H_4N , where X is an atom such as Cl or a group such as CH_3 . The following table gives K_a values for the acids derived from a variety of substituted pyridines.



Atom or Group X	K_a of Conjugate Acid
NO_2	5.9×10^{-2}
Cl	1.5×10^{-4}
H	6.8×10^{-6}
CH_3	1.0×10^{-6}

- (a) What is the pH of a 0.050 M solution of the acid with X = H?
- 1.30
 - 3.23
 - 5.17
 - 6.50
- (b) Suppose each acid is dissolved in sufficient water to give a 0.050 M solution. Which substituent X would lead to the lowest pH? X = _____
- (c) Which of the substituted pyridines is the strongest Brønsted base? X = _____

LABORATORY (4 points) You have a solution that contains Pb^{2+} , Al^{3+} , Fe^{3+} , and Ni^{2+} . You add 6 M HCl and obtain a white precipitate. You centrifuge and decant the supernatant solution. Your kindly lab instructor says that you have only 2 more minutes, so you quickly do the following: You add sodium hydroxide and obtain a gloppy brown-orange precipitate. When the precipitate is treated with aqueous HCl it all dissolves. When the resulting solution is then treated with ammonia, you again see a brown-orange precipitate, and, after centrifuging, the solution is colorless. Unfortunately, you are out of time and can do no more tests. Nonetheless, you are very clever and have a reasonable idea of what is or is not in your unknown.

The ions probably present are _____

The ions probably absent are _____

The ions for which there is not enough information to decide on their presence or absence are _____