QUESTIONS ABOUT ACIDS AND BASES

1. A Brønsted-Lowry **acid** is defined as a proton (H^+) donor.
   A Brønsted-Lowry **base** is defined as a proton (H^+) acceptor.

2. In order to function as a proton (H^+) donor the species must have at least one H in the formula.

3. In order to function as a proton (H^+) acceptor the species must have at least one unshared pair of electrons to bond to the incoming proton (H^+).

4. The products are the conjugate acid (of the reactant base) and the conjugate base (of the reactant acid). The conjugate acid is defined as the acid created when a reactant base accepts one H^+. The conjugate base is defined as the base created when a reactant acid donates one H^+.

5. a. H_3O^+ b. H_2O c. NH_4^+ d. HX e. H_2X^+

6. a. OH^- b. O^{-2} c. NH_2^- d. X^- e. H_2O

7. In terms of their reaction with water, a strong acid is defined as any acid that reacts with water to form H_3O^+ and the conjugate base to a **large extent**. A weak acid is then defined as any acid that reacts with water to form H_3O^+ and the conjugate base to a **small extent**.

8. Reaction of a strong acid and water: $HX + H_2O \longrightarrow H_3O^+ + X^-$

   Reaction of a weak acid and water: $HX + H_2O \longrightarrow H_3O^+ + X^-$

   There is no difference between the **equation** for a strong acid reacting with water and the **equation** for a weak acid reacting with water. The only difference between a strong and a weak acid is the extent of reaction (see problem 7).

9. The six common strong acids are: HCl, HBr, HI, HNO_3, H_2SO_4, and $HClO_4$. The other acids are classified as weak acids.

10. a. $[Na^+] = [Cl^-] = 0.25$ M   b. $[Ca^{+2}] = 0.50$ M and $[Cl^-] = 1.0$ M

    c. $[NH_4^+] = 0.30$ M and $[SO_4^{-2}] = 0.15$ M

11. The inventory of 1 M HCl is $[H_3O^+] = 1$ M and $[Cl^-] = 1$ M.

    The inventory of a 1 M solution of any strong acid, HX, is $[H_3O^+] = 1$ M and $[X^-] = 1$ M.

    The inventory of a 1 M solution of any weak acid, HY, is $[HY] = 1$ M.

12. Liquid HCl does not conduct because HCl is a molecule and therefore without being involved in some kind of ionization process (like an acid/base reaction) the liquid HCl contains no ions to support conductivity.

When the HCl was added to the water to form the 1 M HCl solution a chemical reaction occurred to a large extent to form H_3O^+ and Cl^-. Thus, the solution contains many ions to support conductivity.
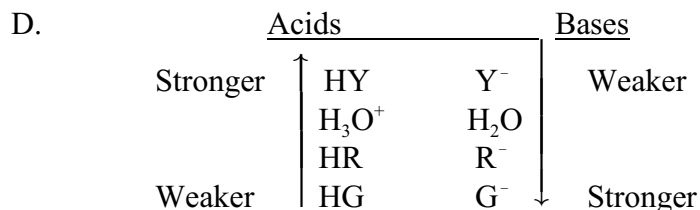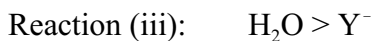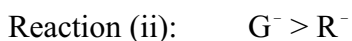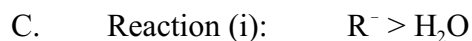
13. Although HCl and $HC_2H_3O_2$ both react as acids with water and the initial amount of HCl and $HC_2H_3O_2$ were the same, the resulting solutions are very different. As mentioned above, HCl reacts with water to a large extent to form H_3O^+ and Cl^- ions and thus the resulting solution contai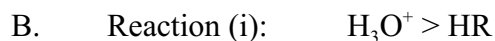ns many ions to support conductivity. On the other hand, $HC_2H_3O_2$ reacts with water to form H_3O^+ and $C_2H_3O_2^-$ ions to only a small extent and therefore the resulting solution contains only a relatively small number of ions to support conductivity. Therefore, 1 M HCl is a good conductor of electricity and 1 M $HC_2H_3O_2$ is a poor conductor of electricity.

14. As mobile ions are necessary for a solution to conduct electricity, it follows that more ions will enable a solution to conduct electricity better. Thus, if the solution of HZ conducts better than the solution of HY, it follows that the HZ solution contains more ions than the HY solution. Therefore the acid HZ must have reacted more with the water to produce ions (H_3O^+ and Z^-) than the acid HY reacted to produce ions (H_3O^+ and Y^-). Thus, acid HZ must be a **stronger** acid than HY.

15. In terms of their reaction with water, a strong base is defined as any base that reacts with water to form OH^- and the conjugate acid to a **large extent**. A weak base is then defined as any base that reacts with water to form OH^- and the conjugate acid to a **small extent**.

16. Reaction of a strong base and water: $B + H_2O \longrightarrow HB^+ + OH^-$

Reaction of a weak acid and water: $B + H_2O \longrightarrow HB^+ + OH^-$

There is no difference between the **equation** for a strong base reacting with water and the **equation** for a weak base reacting with water. The only difference between a strong and a weak base is the extent of reaction (see problem 15).
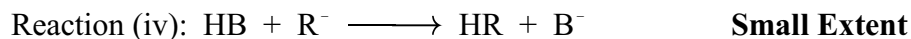
17. The ten common strong bases are: N^{-3}, P^{-3}, As^{-3}, O^{-2}, S^{-2}, Se^{-2}, Te^{-2}, H^-, NH_2^-, and NH^{-2}. The other bases are classified as weak bases.

18. The inventory of 1 M Na_2O is $[Na^+] = 2$ M and $[OH^-] = 2$ M.

Recall that the O^{-2} ion is a strong base and therefore reacts with water to form its conjugate acid (OH^-) and the conjugate base of water (OH^-)!

The inventory of a 1 M solution of any strong base, B, is $[HB^+] = 1M$ and $[OH^-] = 1$ M.

The inventory of a 1 M solution of any weak base, B, is $[B] = 1$ M.

19. Liquid NH_3 does not conduct because NH_3 is a molecule and therefore without being involved in some kind of ionization process (like an acid/base reaction) the liquid NH_3 contains no ions to support conductivity.

When the NH_3 was added to the water to form the 1 M NH_3 solution a chemical reaction occurred to a small extent to form NH_4^+ and OH^-. Thus, the solution contains a few ions to support some conductivity.
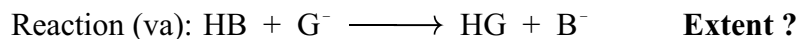
20. The conductivity of solutions of molecular acids and molecular bases is due to these materials reacting with the water solvent to create ions. The stronger the acid (or base), the more conductive the resulting solution will be. Therefore the degree of conductivity gives a measure of the strength of the acid (or base). However, for **ionic** acids (or bases) the solutions will always be highly conductive since the solutions will **always** contain many ions regardless of strength (after all, the solutes are ionic). Therefore, conductivity is **useless** in assessing the acid (or base) strengths of ionic acids (or bases).

21. As discussed in problem 14 above, mobile ions are necessary for a solution to conduct electricity. More ions will enable a solution to conduct electricity better. Thus, if the solution of Z conducts better than the solution of Y, it follows that the Z solution contains more ions than the Y solution. Therefore the base Z must have reacted more with the water to produce ions (HZ^+ and OH^-) than the base Y reacted to produce ions (HY^+ and OH^-). Thus, base Z must be a **stronger** base than Y.
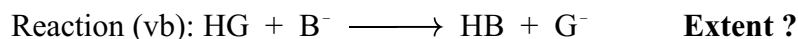
22. A. Reaction (i): $\quad HR + H_2O \longrightarrow H_3O^+ + R^-$ **Small Extent**

   Reaction (ii): $\quad HR + G^- \longrightarrow HG + R^-$ **Large Extent**

   Reaction (iii): $\quad HY + H_2O \longrightarrow H_3O^+ + Y^-$ **Large Extent**

   B.   Reaction (i): $\quad H_3O^+ > HR$

   Reaction (ii): $\quad HR > HG$

   Reaction (iii): $\quad HY > H_3O^+$

   C.   Reaction (i): $\quad R^- > H_2O$

   Reaction (ii): $\quad G^- > R^-$

   Reaction (iii): $\quad H_2O > Y^-$

   D.

	Acids		Bases
Stronger	HY	Y^-	Weaker
	H_3O^+	H_2O	
	HR	R^-	
Weaker	HG	G^-	Stronger
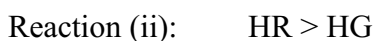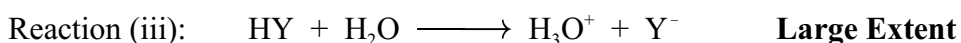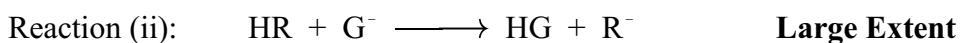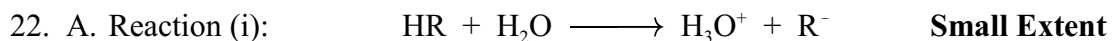
   E. The reaction involved is:

   Reaction (iv): $HB + R^- \longrightarrow HR + B^-$ **Small Extent**

   Since the solution is deep red then there must be a lot of R^- present and therefore the reaction only went to a small extent. Thus, $B^- > R^-$ as bases and $HR > HB$ as acids. This arrangement places HB below HR on the table. It is unclear whether it is stronger or weaker than HG. To decide on the relative strength of HB and HG as acids (also B^- and G^- as bases) ONE of the two following reactions must be performed and the extent of reaction determined.
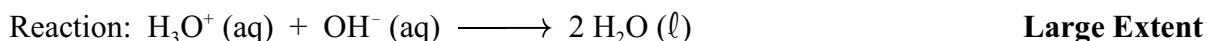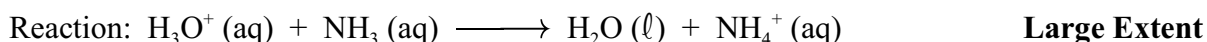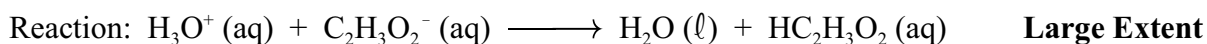
   Reaction (va): $HB + G^- \longrightarrow HG + B^-$ **Extent ?**

   OR

   Reaction (vb): $HG + B^- \longrightarrow HB + G^-$ **Extent ?**

QUESTIONS ON EQUATION WRITING

23. a. Inventory of 0.1 M HCl: $[H_3O^+] = 0.1$ M , $[Cl^-] = 0.1$ M.
Inventory of 0.1 M KOH: $[K^+] = 0.1$ M , $[OH^-] = 0.1$ M.

Reaction: H_3O^+ (aq) + OH^- (aq) $\longrightarrow$ 2 H_2O (ℓ) **Large Extent**

b. Inventory of 0.1 M HNO_3: $[H_3O^+] = 0.1$ M , $[NO_3^-] = 0.1$ M.
Inventory of 0.1 M NH_3 : $[NH_3] = 0.1$ M.

Reaction: H_3O^+ (aq) + NH_3 (aq) $\longrightarrow$ H_2O (ℓ) + NH_4^+ (aq) **Large Extent**

c. Inventory of 0.1 M H_2SO_4 : $[H_3O^+] = 0.1$ M , $[HSO_4^-] = 0.1$ M.
Inventory of 0.1 M $NaC_2H_3O_2$: $[Na^+] = 0.1$ M , $[C_2H_3O_2^-] = 0.1$ M.

Reaction: H_3O^+ (aq) + $C_2H_3O_2^-$ (aq) $\longrightarrow$ H_2O (ℓ) + $HC_2H_3O_2$ (aq) **Large Extent**

d. Inventory of 0.1 M $NaHSO_4$: $[Na^+] = 0.1$ M , $[HSO_4^-] = 0.1$ M.
Inventory of 0.1 M $NaC_2H_3O_2$: $[Na^+] = 0.1$ M , $[C_2H_3O_2^-] = 0.1$ M.

Reaction: HSO_4^- (aq) + $C_2H_3O_2^-$ (aq) $\longrightarrow$ SO_4^{-2} (aq) + $HC_2H_3O_2$ (aq) **Large Extent**
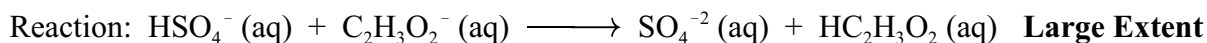
e. Inventory of 0.1 M NH_4Cl: $[NH_4^+] = 0.1$ M , $[Cl^-] = 0.1$ M.
Inventory of 0.1 M NaOH: $[Na^+] = 0.1$ M , $[OH^-] = 0.1$ M.

Reaction: NH_4^+ (aq) + OH^- (aq) $\longrightarrow$ H_2O (ℓ) + NH_3 (aq) **Large Extent**
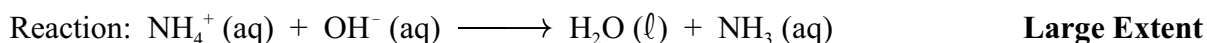
f. Inventory of 0.1 M $NaHCO_3$: $[Na^+] = 0.1$ M , $[HCO_3^-] = 0.1$ M.
Inventory of 0.1 M KOH: $[Li^+] = 0.1$ M , $[OH^-] = 0.1$ M.

Reaction: HCO_3^- (aq) + OH^- (aq) $\longrightarrow$ H_2O (ℓ) + CO_3^{-2} (aq) **Large Extent**

g. Inventory of 0.1 M $HC_2H_3O_2$: $[HC_2H_3O_2] = 0.1$ M.
Inventory of 0.1 M $NaC_2H_3O_2$: $[Na^+] = 0.1$ M , $[C_2H_3O_2^-] = 0.1$ M.

Reaction: $HC_2H_3O_2$ (aq) + $C_2H_3O_2^-$ (aq) $\longrightarrow$ $C_2H_3O_2^-$ (aq) + $HC_2H_3O_2$ (aq)
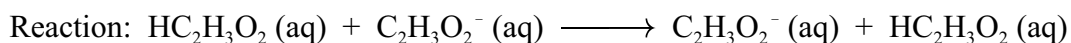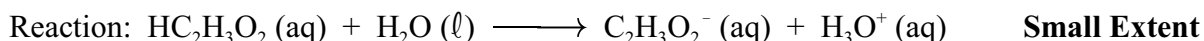
NOTE: This reaction is between the strongest acid and the strongest base present in appreciable amount but as the reactants and products are the same, the reaction goes nowhere!

h. Inventory of 0.1 M $HC_2H_3O_2$: $[HC_2H_3O_2] = 0.1$ M.
Inventory of 0.1 M $MgSO_4$: $[Mg(H_2O)_6^{+2}] = 0.1$ M , $[SO_4^{-2}] = 0.1$ M.

Reaction: $HC_2H_3O_2$ (aq) + SO_4^{-2} (aq) $\longrightarrow$ $C_2H_3O_2^-$ (aq) + HSO_4^- (aq) **Small Extent**

i. Inventory of 0.1 M $HC_2H_3O_2$: $[HC_2H_3O_2] = 0.1$ M.

Reaction: $HC_2H_3O_2$ (aq) + H_2O (ℓ) $\longrightarrow$ $C_2H_3O_2^-$ (aq) + H_3O^+ (aq) **Small Extent**
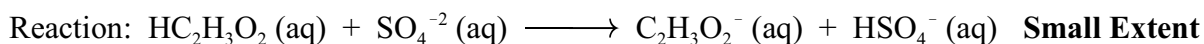
j. Inventory of pure HNO_3 is HNO_3.
Inventory of pure NaOH is NaOH.

Reaction: HNO_3 (ℓ) + NaOH (s) $\longrightarrow$ H_2O (ℓ) + Na^+ (aq) + NO_3^- (aq) **Large Extent**
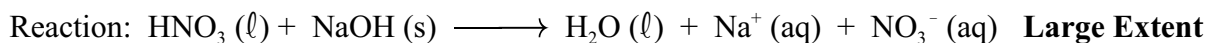
QUESTIONS ON OXIDATION AND REDUCTION

24. **Oxidation** is the process in which electrons are formally lost.
    Reduction is the process in which electrons are formally gained.

25. An **oxidizer** is the chemical that causes some other chemical to undergo oxidation (the loss of electrons). The oxidizer does this by taking away (or gaining) electrons from the other chemical.

    A **reducer** is the chemical that causes some other chemical to undergo reduction (the gain of electrons). The reducer does this by giving away (or losing) electrons to the other chemical.

26. The products of any redox reaction are another oxidizer and another reducer (called the conjugate oxidizer and conjugate reducer). Note the similarity to the products of an acid/base reaction.

27. Other than the fact that both oxidation states and formal charges are calculated numbers and therefore do not really exist, there is no connection between the concepts of oxidation states and formal charges. Formal charges are used to determine the plausibility of a given Lewis structure while oxidation states are used to follow electrons in redox reactions.

28. For a MAIN GROUP ELEMENT (s and p block element) **that reacts**, the theoretical maximum and minimum oxidation states are determined from the elements position relative to the noble gas family.

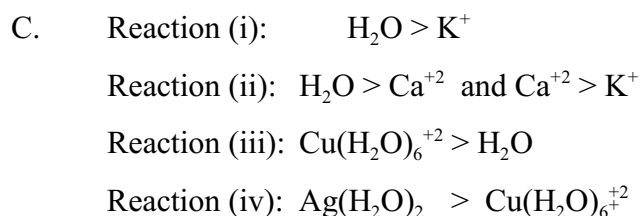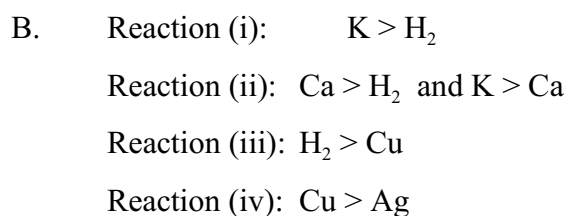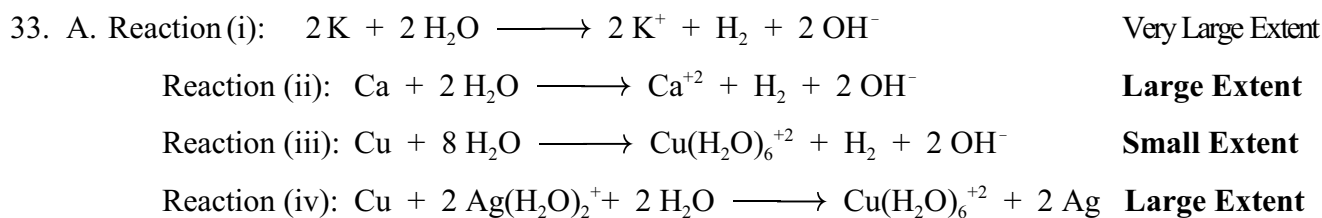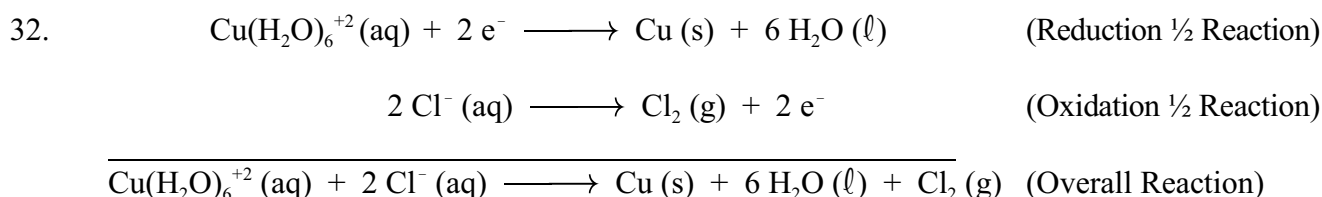   The maximum oxidation state is given by: **Max Ox State = +(Group Number)**

    The minimum oxidation state is given by: **Min Ox State = (Group Number – 8)**

    a. N (group 5) Max Ox State = Group# = +5
             Min Ox State = (Group # – 8) = (5 – 8) = –3

    b. Xe (group 8) Max Ox State = Group# = +8
             Min Ox State = (Group # – 8) = (8 – 8) = 0

    c. Cl (group 7) Max Ox State = Group# = +7
             Min Ox State = (Group # – 8) = (7 – 8) = –1

    d. Na (group 1) Max Ox State = Group# = +1
             Min Ox State = (Group # – 8) = (1 – 8) = –7 Never achieved!

    e. Se (group 6) Max Ox State = Group# = +6
             Min Ox State = (Group # – 8) = (6 – 8) = –2

    f. Ca (group 2) Max Ox State = Group# = +2
             Min Ox State = (Group # – 8) = (2 – 8) = –6 Never Achieved!

    g. C (group 4) Max Ox State = Group# = +4
             Min Ox State = (Group # – 8) = (4 – 8) = –4

    h. B (group 3) Max Ox State = Group# = +3
             Min Ox State = (Group # – 8) = (3 – 8) = –5

29.

a. $\overset{(+)}{Cs}$ $\overset{(+7)}{Cl}$ $\overset{(-2)}{O_4}$ b. $\overset{(+6)}{S}$ $\overset{(-2)}{O_3}$ c. $\overset{(+6)}{U}$ $\overset{(-1)}{F_6}$

d. $\overset{(+4)}{Xe}$ $\overset{(-1)}{F_4}$ e. $\overset{(+)}{K}$ $\overset{(+5)}{N}$ $\overset{(-2)}{O_3}$ f. $\overset{(+3)}{Al_2}$ $(\overset{(+6)}{S}$ $\overset{(-2)}{O_4})_3$

g. $\overset{(+1)}{Cs}$ $\overset{(-1)}{H}$ h. $\overset{(+1)}{Na_2}$ $\overset{(+6)}{Cr_2}$ $\overset{(-2)}{O_7}$ i. $\overset{(+8)}{Os}$ $\overset{(-2)}{O_4}$

j. $(\overset{(-3)}{N}$ $\overset{(+1)}{H_4})_2$ $\overset{(+4)}{C}$ $\overset{(-2)}{O_3}$ k. $\overset{(+2)}{Ba}$ $\overset{(-2)}{Se}$ l. $\overset{(0)}{S_8}$

m. $\overset{(+2)}{Mg_3}$ $\overset{(+6)}{U}$ $\overset{(-2)}{O_6}$ n. $\overset{(+5)}{N}$ $\overset{(-2)}{O_2}^+$ o. $\overset{(+2)}{Sr}$ $\overset{(-1)!!!}{O_2}$

p. $\overset{(+8)}{Xe}$ $\overset{(-2)}{O_6}^{-4}$ q. $\overset{(+6)}{S_2}$ $\overset{(-2)}{O_7}^{-2}$ r. $\overset{(-3)}{As}$ $\overset{(+1)}{H_3}$

30. a. The Ox. St. of Mn increases from +4 in MnO_2 to +7 in MnO_4^- and thus the Mn lost 3 electrons during the reaction. Therefore, Mn underwent an oxidation.

b. The Ox. St. of Bi decreases from +5 in BiO_3^- to +3 in Bi^{+3} and thus the Bi gained 2 electrons during the reaction. Therefore, Bi underwent a reduction.

c. The Ox. St. of S increases from +4 in SO_2 to +6 in SO_3 and thus the S lost 2 electrons during the reaction. Therefore, S underwent an oxidation.

d. The Ox. St. of Cl increases from +1 in OCl^- to +5 in ClO_3^- and thus the Cl lost 4 electrons during the reaction. Therefore, Cl underwent an oxidation.

e. The Ox. St. of N decreases from +4 in N_2O_4 to +1 in N_2O and thus the N gained 3 electrons each during the reaction. Therefore, N underwent a reduction.

f. The Ox. St. of O decreases from −1 in H_2O_2 to −2 in H_2O and thus the O gained 1 electron each during the reaction. Therefore, O underwent a reduction.

31. As mentioned in problem 43, the oxidizing agent (or oxidant or oxidizer) is the chemical that gains electrons from the other chemical. The reducing agent (or reductant or reducer) is the chemical that loses electrons to the other chemical.

a. The Cl_2 gains electrons to form Cl^- and therefore the Cl_2 is the oxidizing agent (or oxidizer). The Br^- loses electrons to form Br_2 and therefore is the reductant (or reducer).

b. The oxidation state of N decreases from +4 in NO_2 to −3 in NH_3. This is the gain of electrons and therefore NO_2 is the oxidizing agent. The oxidation state of H increases from 0 in H_2 to +1 in NH_3 and H_2O. This is the loss of electrons and therefore H_2 is the reducing agent.
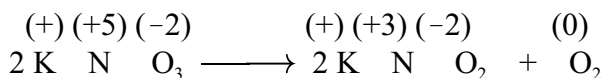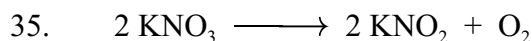
c. The oxidation state of Mn decreases from +7 in MnO_4^- to +2 in Mn^{+2}. This is the gain of electrons and therefore MnO_4^- is the oxidizing agent. The oxidation state of S increases from +4 in SO_3^{-2} to +6 in SO_4^{-2}. This is the loss of electrons and therefore SO_3^{-2} is the reducing agent.

d. The oxidation state of Cl decreases from +1 in ClO^- to -1 in Cl^-. This is the gain of electrons and therefore ClO^- is the oxidizing agent. The oxidation state of Cr increases from +3 in $Cr(OH)_3$ to +6 in CrO_4^{-2}. This is the loss of electrons and therefore $Cr(OH)_3$ is the reducing agent.

e. The oxidation state of Cl decreases from 0 in Cl_2 to -1 in Cl^-. This is the gain of electrons and therefore Cl_2 is the oxidizing agent. The oxidation state of Cl increases from 0 in Cl_2 to +1 in HClO. This is the loss of electrons and therefore Cl_2 is the reducing agent. Cl_2 acts as both the oxidizing agent and the reducing agent in this case. This is called a disproportionation reaction.

32. $\qquad$ $Cu(H_2O)_6^{+2}(aq) + 2\,e^- \longrightarrow Cu\,(s) + 6\,H_2O\,(\ell)$ $\qquad$ (Reduction ½ Reaction)

$\qquad\qquad\qquad$ $2\,Cl^-\,(aq) \longrightarrow Cl_2\,(g) + 2\,e^-$ $\qquad\qquad$ (Oxidation ½ Reaction)

$\overline{Cu(H_2O)_6^{+2}\,(aq) + 2\,Cl^-\,(aq) \longrightarrow Cu\,(s) + 6\,H_2O\,(\ell) + Cl_2\,(g)}$ (Overall Reaction)

33. A. Reaction (i): $\quad 2\,K + 2\,H_2O \longrightarrow 2\,K^+ + H_2 + 2\,OH^-$ $\qquad$ Very Large Extent

$\qquad$ Reaction (ii): $Ca + 2\,H_2O \longrightarrow Ca^{+2} + H_2 + 2\,OH^-$ $\qquad$ **Large Extent**

$\qquad$ Reaction (iii): $Cu + 8\,H_2O \longrightarrow Cu(H_2O)_6^{+2} + H_2 + 2\,OH^-$ $\qquad$ **Small Extent**

$\qquad$ Reaction (iv): $Cu + 2\,Ag(H_2O)_2^+ + 2\,H_2O \longrightarrow Cu(H_2O)_6^{+2} + 2\,Ag$ **Large Extent**

B. $\qquad$ Reaction (i): $\qquad K > H_2$

$\qquad$ Reaction (ii): $Ca > H_2$ and $K > Ca$

$\qquad$ Reaction (iii): $H_2 > Cu$

$\qquad$ Reaction (iv): $Cu > Ag$

C. $\qquad$ Reaction (i): $\qquad H_2O > K^+$

$\qquad$ Reaction (ii): $H_2O > Ca^{+2}$ and $Ca^{+2} > K^+$

$\qquad$ Reaction (iii): $Cu(H_2O)_6^{+2} > H_2O$

$\qquad$ Reaction (iv): $Ag(H_2O)_2 > Cu(H_2O)_6^{+2}$

D.   <u>Reducers</u>   <u>Oxidizers</u>

Stronger	K	K^+	Weaker
	Ca	Ca^{+2}	
	H_2	H_2O	
	Cu	Cu^{+2}	
Weaker	Ag	Ag^+	Stronger

34.   a. $2\,Na + I_2 \longrightarrow 2\,Na^+ + 2\,I^-$ (or 2 NaI if no solvent is present)

      b. $16\,Cs + S_8 \longrightarrow 16\,Cs^+ + 8\,S^{-2}$ (or $8\,Cs_2S$ if no solvent is present)

      c. $6\,Mg + P_4 \longrightarrow 6\,Mg^{+2} + 4\,P^{-3}$ (or $2\,Mg_3P_2$ if no solvent is present)

      d. $4\,Al + 3\,O_2 \longrightarrow 4\,Al^{+3} + 6\,O^{-2}$ (or $2\,Al_2O_3$ if no solvent is present)

      e. $2\,Be + O_2 \longrightarrow 2\,Be^{+2} + 2\,O^{-2}$ (or 2 BeO if no solvent is present)

      f. $4\,Li + O_2 \longrightarrow 4\,Li^+ + 2\,O^{-2}$ (or $2\,Li_2O$ if no solvent is present)

           (0)   (0)   (+4)(−2)
      g. $C + O_2 \longrightarrow CO_2$

      h. $Zn + Br_2 \longrightarrow Zn^{+2} + 2\,Br^-$ (or $ZnBr_2$ if no solvent is present)

      i. $4\,Sc + 3\,O_2 \longrightarrow 4\,Sc^{+3} + 6\,O^{-2}$ (or $2\,Sc_2O_3$ if no solvent is present)

      j. $2\,K + H_2 \longrightarrow 2\,K^+ + 2\,H^-$ (or 2 KH if no solvent is present)

      k. $Ba + H_2 \longrightarrow Ba^{+2} + 2\,H^-$ (or BaH_2 if no solvent is present)

           (0)   (0)   (+5)(−1)
      l. $P_4 + 10\,F_2 \longrightarrow 4\,PF_5$

           (0)   (0)   (+1)(−1)
      m. $H_2 + Br_2 \longrightarrow 2\,HBr$

           (0)   (0)   (+1)(−1)
      n. $8\,H_2 + S_8 \longrightarrow 8\,H_2S$

           (0)   (0)   (+1)(−1)
      o. $2\,H_2 + O_2 \longrightarrow 2\,H_2O$

35. $2\,KNO_3 \longrightarrow 2\,KNO_2 + O_2$

      (+) (+5) (−2)   (+) (+3) (−2)   (0)
      $2\,K$ N $O_3 \longrightarrow 2\,K$ N $O_2 + O_2$

The "N" in KNO_3 was reduced from +5 to +3 and part of the "O" in KNO_3 was oxidized from −2 to zero. The KNO_3 itself underwent both oxidation (to O_2) and reduction (to KNO_2).

QUESTIONS ABOUT COLLIGATIVE PROPERTIES OF SOLUTIONS

36. Raoult's law states that for a solution of a nonvolatile solute in a volatile liquid solvent the vapor pressure above the solution is equal to the mole fraction of the solvent in the solution times the vapor pressure of the pure solvent. Raoult's law is not valid for a volatile solute as both the solvent and solute would evaporate under these conditions. Raoult's law can be used to determine the separate vapor pressures of the two volatile liquids which can then be summed to get the overall vapor pressure above the solution of two volatile components.

37. The phase diagram of the solution is similar to that of the pure solvent but is off-set with the freezing point of the solution lying below that of the solvent and the boiling point of the solution lying above that of the solvent.

38. $$X_{H_2O} = \frac{500.0 \text{ g H}_2\text{O} \times \dfrac{1 \text{ mol H}_2\text{O}}{18.0152 \text{ g H}_2\text{O}}}{(500.0 \text{ g H}_2\text{O} \times \dfrac{1 \text{ mol H}_2\text{O}}{18.0152 \text{ g H}_2\text{O}}) + (44.0 \text{ g C}_3\text{H}_8\text{O}_3 \times \dfrac{1 \text{ mol C}_3\text{H}_8\text{O}_3}{92.094 \text{ g C}_3\text{H}_8\text{O}_3})} = 0.983$$

$$P_{H_2O} = X_{H_2O} \bullet P^0_{H_2O} = 0.983 \bullet 23.8 \text{ torr} = 23.4 \text{ torr}$$

39. $\Delta T_f = K_f \bullet m = -1.86 \text{ °C/m} \bullet 0.111 \text{ m} = -0.206 \text{ °C}$

Therefore the FP is also −0.206 °C.

40. $$\Delta T_f = K_f \bullet m = -5.12 \text{ °C/m} \times \frac{6.41 \text{ g C}_8\text{H}_{10} \times \dfrac{1 \text{ mol C}_8\text{H}_{10}}{106.167 \text{ g C}_8\text{H}_{10}}}{469 \text{ g C}_6\text{H}_6 \times \dfrac{1 \text{ kg C}_6\text{H}_6}{1000 \text{ g C}_6\text{H}_6}} = -0.659 \text{ °C}$$

Therefore the FP = 5.50 °C − 0.659 °C = 4.84 °C.

41. $$\Delta T_b = K_b \bullet m = 1.22 \text{ °C/m} \times \frac{3.43 \text{ g C}_8\text{H}_8\text{O}_3 \times \dfrac{1 \text{ mol C}_8\text{H}_8\text{O}_3}{152.149 \text{ g C}_8\text{H}_8\text{O}_3}}{50.0 \text{ g Eth} \times \dfrac{1 \text{ kg Eth}}{1000 \text{ g Eth}}} = 0.550 \text{ °C}$$

Therefore the BP = 78.50 °C + 0.550 °C = 79.05 °C.

42. a) iii) , ii) , i) b) i) , ii) , iii) c) iii) , ii) , i)

43. $$\Delta T_f = K_f \bullet m = K_f \times \frac{\dfrac{\text{g solute}}{\text{MM solute}}}{\text{kg solvent}} \quad \text{or} \quad MM = \frac{K_f \times \text{g solute}}{\Delta T_f \times \text{kg solvent}}$$

$$MM = \frac{7.40 \text{ °C} \bullet \text{kgphenol/mol} \times 0.937 \text{ g caf}}{-0.357 \text{ °C} \times 0.100 \text{ kg phenol}} = 194 \text{ g/mol}$$

44. No, the vapor is always more concentrated in the more volatile component that is the liquid. By definition, the more volatile component vaporizes more readily than the less volatile component. Thus a greater amount of the of the more volatile component vaporizes than the less volatile component which leads to an enrichment of the vapor in terms of the more volatile component over the liquid.

45. $P_{CH_2Cl_2} = X_{CH_2Cl_2} \cdot P^0_{CH_2Cl_2} = \dfrac{1.50 \text{ mol } CH_2Cl_2}{1.50 \text{ mol } CH_2Cl_2 + 1.00 \text{ mol } CCl_4} \times 352 \text{ torr} = 211._4 \text{torr}$
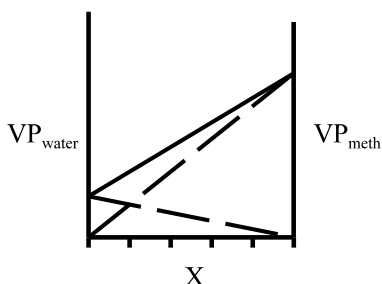
$P_{CCl_4} = X_{CCl_4} \cdot P^0_{CCl_4} = \dfrac{1.00 \text{ mol } CCl_4}{1.50 \text{ mol } CH_2Cl_2 + 1.00 \text{ mol } CCl_4} \times 118 \text{ torr} = 47.2_0 \text{torr}$

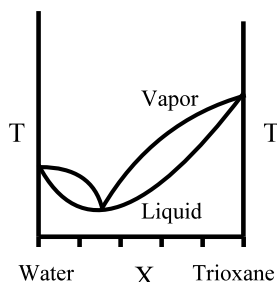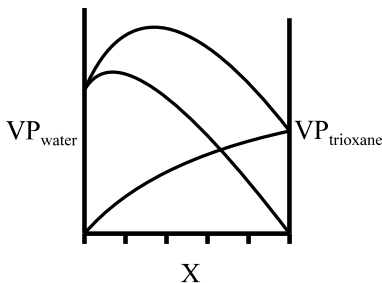Therefore the total pressure, $P_{tot} = 211._4$ torr $+ 47.2_0$ torr $= 258._6$ torr.

The composition of the vapor is given by Dalton law of partial pressures.

$P_a = X_a \cdot P_{tot}$ or $X_a = \dfrac{P_a}{P_{tot}}$ $X_{CCl_4} = 1 - X_{CH_2Cl_2}$ Therefore 0.817 = 0.183

46.
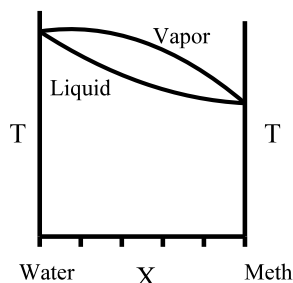
47.

48. $\Pi = M \cdot R \cdot T = \dfrac{0.10 \text{ mol}}{L} \times \dfrac{0.082058 \text{ L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times 298._{15} \text{ K} = 2.4 \text{ atm}$

49. $\Pi = M \cdot R \cdot T = \dfrac{\frac{\text{g solute}}{\text{MM solute}}}{\text{L soln}} \times R \cdot T$ or $MM = \dfrac{\text{g solute} \times R \times T}{\Pi \times \text{L soln}}$

$MM = \dfrac{4.64 \text{ g protein} \times 0.082058 \text{ L} \cdot \text{atm/mol} \cdot \text{K} \times 288._{15}\text{K}}{11.2 \text{ torr} \times \dfrac{1 \text{ atm}}{760 \text{ torr}} \times 1 \text{ L soln}} = 7.44 \times 10^3 \text{ g protein/mol}$