QUESTIONS ABOUT ACIDS AND BASES

1. What is the definition of a Brønsted-Lowry acid? What is the definition of a Brønsted-Lowry base?

2. What chemical feature MUST be present IF a species is to function as a Brønsted-Lowry acid? This is not to say that any chemical that possesses this feature WILL function as a Brønsted-Lowry acid.

3. What chemical feature MUST be present IF a species is to function as a Brønsted-Lowry base? This is not to say that any chemical that possesses this feature WILL function as a Brønsted-Lowry base.

4. What are the products of any acid/base reaction?

5. What are the conjugate acids of the following species?

   a) H_2O b) OH^- c) NH_3 d) X^- e) HX

6. What are the conjugate bases of the following species?
   a) H_2O b) OH^- c) NH_3 d) HX e) H_3O^+

7. In terms of their reaction with water, how are strong acids defined? How are weak acids defined?

8. Write the equation for the reaction of a strong acid, HX, with water. Write the equation for the reaction of a weak acid, HX, with water. What is the difference between the two equations? Explain.

9. What are the six common strong acids? Memorize them! How then, are all other acids classified?

10. The processing of determining the identity and concentration of solutes present in appreciable amounts in a solution is called **inventorying**. Inventory the following solutions.

    a) 0.25 M NaCl   b) 0.50 M $Ca(NO_3)_2$ c) 0.15 M $(NH_4)_2SO_4$

11. What is the inventory of 1M HCl? What is the inventory of a 1 M solution of any strong acid, HX? A 1 M solution of any weak acid, HY?

12. Explain why liquid HCl does not conduct electricity but a 1M HCl solution does conduct.

13. How would the conductivity of a 1M HCl solution differ from the conductivity of a 1M $HC_2H_3O_2$ solution? Explain.

14. If the conductivity of an aqueous solution of acid HZ were such that the 150 watt bulb lit brightly while the aqueous solution of acid HY lit only the 7.5 watt bulb dimly, what conclusion can one safely draw from these observations about the relative acid strengths of HZ and HY? Explain.

15. In terms of their reaction with water, how are strong bases defined? How are weak bases defined?

16. Write the equation for the reaction of a strong base, B, with water. Write the equation for the reaction of a weak base, B, with water. What is the difference between the two equations? Explain.

17. What are the ten common strong bases? Memorize them! How then, are all other bases classified?

18. What is the inventory of a 1M Na_2O solution? What is the inventory of a 1 M solution of any strong base? A 1 M solution of any weak base?

19. Explain why liquid NH_3 does not conduct electricity but a 1M NH_3 solution does conduct (slightly).

20. Explain why conductivity can be used to determine the relative strengths amongst a group of molecular acids or amongst a group of molecular bases but cannot be used to determine the relative strengths amongst a group of ionic acids or amongst a group of ionic bases.

21. If the conductivity of an aqueous solution of base Z was such that the 7.5 watt bulb lit brightly while the aqueous solution of base Y lit only the 7.5 watt bulb dimly, what conclusion can one safely draw from these observations about the relative base strengths of Z and Y? Explain.

22. You are given the hypothetical acids HR, HG, and HY which are colorless, in the pure form. Their respective bases however, are highly colored; R^- being red, G^- being green, and Y^- being yellow in solution. Consider the following experiments.

    i. When HR is mixed with water, the resulting solution is only a faint pink.

    ii. When a solution of HR (eg. 1M HR) is mixed with a solution containing G^- (eg. 1M NaG) the resulting solution is a deep red color.

    iii. When HY is mixed with water, the resulting solution is a deep yellow.

    A)   Write the equations which correspond to the changes in each of the above reactions and indicate the relative extent to which each occurred.

    B) For each of the equations in A, decide which acid is the stronger, the acid on the left side or the acid on the right side.

    C) For each of the equations in A, decide which base is the stronger, the base on the left side or the base on the right side.

    D)   Now prepare an acid/base table similar to the one presented in class which lists your FOUR acids and their FOUR conjugate bases. Consult your notes to see how to properly list them!

    E) If a solution of a fourth acid, HB (eg. 1M HB) (which is colorless), is mixed with a solution of R^- (eg. 1M NaR) and the resulting solution is a deep red, where does the acid HB belong in your table? Can it be placed unambiguously? If not what reaction or reactions would you perform in order to correctly place acid HB in your chart?

Review: Writing Correct Chemical Equations

The word "correct," in the above statement may appear to be an unnecessary adjective. This is because one may legitimately ask the question, "How could an incorrect chemical equation ever be considered a chemical equation in the first place?" Nevertheless, it is an unfortunate reality that the chemical literature does contain incorrect chemical equations. How can this be the case? After all, if we establish an overall balance of total atoms and total charge between product and reactant substance, do we not then have a correct chemical equation? To find out, let's reexamine the criteria for an equation.

Clearly, if we write any such balanced statements, we obtain an algebraically-acceptable equation. But,does this mean necessarily that we have a chemically-acceptable equation? To this, we must recognize that the answer is "No!" An equation is hardly of value unless the equation deals with the chemical problem at hand. Recall, that an equation **must be in accord with the chemical facts** and **must contain only the chemically pertinent species**. Hence, the real problem in writing chemical equations stems from the necessity to correctly identify the reactant and product substances, a task which frequently is difficult because the chemical nature of any material can be known only from reliable experimental results.

To be sure, then, the exact makeup of any chemical substance is known only within the boundaries of experimental accuracy. Thus, when we write formulas in equations, these formulas should constitute the **simplest and best chemical representation that we know** for the reactants and products.

A beginner in chemistry, therefore, must have learned from either some prior experience what the products and reactants are, or he must look up this information if it is available, or he must be told! For without first-hand knowledge as to what are the products and reactants, one CAN NOT write a correct, meaningful, chemical equation. Let us now consider some examples.

A. Suppose that you are in a laboratory and are directed to the reagent shelf, whereupon you observe two large bottles, each of which contains a clear, colorless, homogenous liquid. One bottle bears the label 0.5 M Na_2CO_3 and the other, 0.5 M $CaCl_2$. Now,you are told (in case you might not know) that both Na_2CO_3 and $CaCl_2$ are white, crystalline, ionic solids under standard laboratory conditions.

Your next direction is to mix two mL of the 0.5 M Na_2CO_3 with two mL of the 0.5 M $CaCl_2$. As soon as you make the mix, you discover that the mixture becomes opaque white and that on standing a white powdery solid separates in rather copious quantity leaving a clear colorless liquid. Clearly then, a reaction occurred upon mixing the solutions.

What is the "correct equation" for this reaction?

Now, if you're careful, you'll back off, don your thinking cap, and recognize that from this very brief laboratory experience you're already in a position to assemble quite a bit of chemical information.

Let's note the pertinent stuff:

1. Both salts, Na_2CO_3 and $CaCl_2$, are very soluble in water. The simple fact that they can be dissolved to an extent of 0.5 M tells you this.

2. Therefore, you may quantitatively inventory each original solution. So what is an inventory of a solution? It is a list of all species which are present in appreciable concentration (other than H_2O; since H_2O is a solvent - it's known to be present in overwhelming abundance, so we don't list it even though we certainly know that it is present).

   The inventory is: $[Na^+] = 1$ & $[CO_3^{-2}] = 0.5$ $[Ca^{+2}] = 0.5$ & $[Cl^-] = 1$
                          For 0.5 M Na_2CO_3,   For 0.5 M $CaCl_2$,

   (Note: [] is called square bracket notation, and it means concentration in moles per liter)

3. You know to write Na^+, CO_3^{-2}, etc., as you have been told that these salts are ionic solids. That is, since they are ionic, you know that when they dissolve in water, they simply dissociate into their constituent ions (unless the constituents react with H_2O to a large extent - a process we have not yet discussed).

Now, with this formation and your practical experience that NaCl (common table salt) is very soluble in water, you can write the correct equation. That is, you realize that you have mixed a solution with an abundance of Na^+ and CO_3^{-2} with a solution with an abundance of Ca^{+2} and Cl^-, which resulted in the immediate formation of a white solid. So what is this solid? By simply permuting the added ingredients, you see that the only possibilities are Na_2CO_3, $CaCl_2$, NaCl, and $CaCO_3$. And from this list you may immediately discharge Na_2CO_3, $CaCl_2$, and NaCl, since you know each of these salts to be very soluble in H_2O. Or, as a chemist might say, Na^+ is compatible with both Cl^- and CO_3^{-2} and Ca^{+2} is compatible with Cl^- in an aqueous environment. Clearly, then, you may recognize logically, without doing any more experiments, that the white solid formed (precipitated) must be $CaCO_3$ (chalk or oyster shells).

Hence the equation is:
$$Ca^{+2} (aq) + CO_3^{-2} (aq) \longrightarrow CaCO_3 (s)$$

Recognize, therefore, that it would have been absolutely incorrect to have written . . .
      (i) $Na_2CO_2 + CaCl_2 \longrightarrow CaCO_3 + 2\ NaCl$

or to have written . . .
      (ii) $Na^+ + CO_3^{-2} + Ca^{+2} + Cl^- \longrightarrow CaCO_3 + NaCl,$

since neither of these statements reflect the actual change which took place when you made the mix. That is, (i) says to a chemist that two solids (or, at the minimum, two pure substances) were mixed, resulting in the production of two different solids. And, (ii) says that upon the simultaneous combination of these four ions (true so far!) that two solids were formed (not true, no solid NaCl was formed at all!).

So realize that the simple combination of two (or more) chemical systems in no way guarantees that a reaction will take place. For instance, if you were to mix 0.1 M NaCl with 0.1 M KNO_3 (another colorless solution), you would observe no change at all other than an increase in overall solution volume.
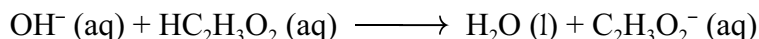
Consequently, to write something like . . .

$$NaCl + KNO_3 \longrightarrow NaNO_3 + KCl$$

or

$$Na^+ + Cl^- + K^+ + NO_3^- \longrightarrow NaNO_3 + KCl$$
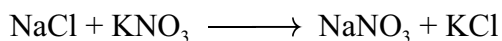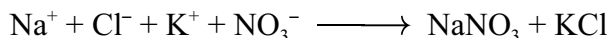
would be utterly ridiculous as no such chemical changes (reactions) would take place upon mixing these solutions. Therefore, the logical consequence of all this is to realize that equations are to be written only for situations wherein there is evidence that is chemical change has indeed taken place.

B. Recall The Laboratory Experiment, "Solution Stoichiometry." In this experiment, you were formally introduced to "concentration." Specifically, you dealt with the "moles per liter" (or "molar," abbreviated as M) concentration of a solution of sodium hydroxide (NaOH). Molar (M) means the amount of solute in moles which are contained in every liter of that particular solution. The solution which was used was 0.50 M NaOH (to two significant figures). So, if you carefully measured out 1.0 L of this solution, and boiled gently until all the water was removed, you would obtain 0.50 moles (20 g) of NaOH: a white, crystalline solid, which is rather hygroscopic (which means the solid absorbs water from the air).

In this experiment you determined the percent of $HC_2H_3O_2$ in a vinegar solution by reacting the $HC_2H_3O_2$ with a NaOH solution of known concentration. Now, if you didn't get this message when you did the experiment, recognize why we stated that "at the equivalence point of the titration (i.e., when the solution in the flask developed a faint, but perceptible and lasting pink color) the moles of NaOH added must equal the moles of $HC_2H_3O_2$ in the 25.00 mL of the vinegar sample." This is because OH^- and $HC_2H_3O_2$ combine chemically on a mole for mole basis.

The correct equation shows this is

$$OH^- \text{ (aq)} + HC_2H_3O_2 \text{ (aq)} \longrightarrow H_2O \text{ (l)} + C_2H_3O_2^- \text{ (aq)}$$

Why not?

$$NaOH + HC_2H_3O_2 \longrightarrow NaC_2H_3O_2 + H_2O, \text{ or } Na^+ + C_2H_3O_2^- + H_2O?$$
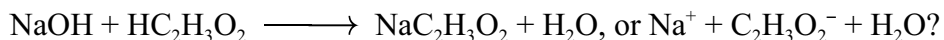
Again, what is NaOH? It is a white, crystalline, hygroscopic solid under standard laboratory conditions. Did you add such a material to the vinegar solution? No! You added a solution which contained Na^+ and OH^-. And when you added this solution to the vinegar, did any white solids form? No again! Therefore, since $NaC_2H_3O_2$ is a white crystalline solid under normal lab conditions, we do not write $NaC_2H_3O_2$ as a product of the titration reaction, because it isn't!

Perhaps you questioned how it was that we know that in the vinegar solution we had a substance (other than H_2O) whose formula was best represented as $HC_2H_3O_2$. That is, if ionic solids dissolve into simpler ingredients (the constituent ions), might not $HC_2H_3O_2$ dissolve in water into simpler ingredients? Yes, this is possible! And in fact this does occur to a small but measurable extent, when $HC_2H_3O_2$ is dissolved in H_2O, the transformation is:

$$HC_2H_3O_2 + H_2O \longrightarrow H_3O^+ + C_2H_3O_2^- \text{ (this goes about 0.1\% for 1 M } HC_2H_3O_2)$$
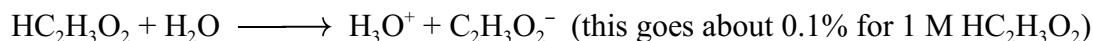
and we shall recognize that materials which are capable of giving up H^+ (proton) in a chemical process are known as acids. Consequently, we see that $HC_2H_3O_2$ is an acid (H_2O is too!). So when we wrote the titration equation, why didn't we write

$$OH^- + H_3O^+? \text{ or } OH^- + HC_2H_3O_2 + H_3O^+?$$
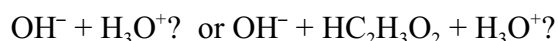
The answer to this is simply that because there is such a very small $[H_3O^+]$ in the vinegar solution, there is no meaningful point in including H_3O^+ in the titration equation. That is, the primary reaction which occurs when we add NaOH solution to vinegar is between the base OH^- and the acid $HC_2H_3O_2$.

So let us sophisticate our appreciation and understanding of equation writing by noting that although more than one reaction may occur when we mix chemical systems, we only write equations for the principal (significant) changes which take place.

What experiment could you (or might you) do to prove that the substance principally present in vinegar, other than H_2O, was $HC_2H_3O_2$ (i.e., **NOT** H_3O^+ and $C_2H_3O_2^-$)? **See Problem 3.**

QUESTIONS ON EQUATION WRITING

23. Write the equation for the principal acid/base reaction which occurs when **equal volumes** of the following solutions are mixed. Also, comment on the extent of the reaction as written.

    (Note: Prior to writing any equations, always begin with a quantitative inventory of each of the solutions which are to be mixed.)

    a. 0.1 M HCl with 0.1 M KOH

    b. 0.1 M HNO_3 with 0.1 M NH_3

    c. 0.1 M H_2SO_4 with 0.1 M $NaC_2H_3O_2$

    d. 0.1 M $NaHSO_4$ with 0.1 M $NaC_2H_3O_2$

    e. 0.1 M NH_4Cl with 0.1 M NaOH

    f. 0.1 M $NaHCO_3$ with 0.1 M LiOH

    g. 0.1 M $HC_2H_3O_2$ with 0.1 M $NaC_2H_3O_2$

    h. 0.1 M $HC_2H_3O_2$ with 0.1 M $MgSO_4$ (NOTE: $Mg(H_2O)_6^{+2}$ is a weaker acid than $HC_2H_3O_2$)

    i. 0.1 M $HC_2H_3O_2$ with H_2O (i.e., vinegar is diluted)

    j. Pure liquid HNO_3 with pure solid NaOH

QUESTIONS ON OXIDATION AND REDUCTION

24. What is the definition of oxidation? What is the definition of reduction?

25. What is the definition of an oxidizer? What is the definition of a reducer?

26. What are the products of any redox reaction?

27. What is the relationship, if any, between the concepts of oxidation state and formal charge? Explain.

28. What is the theoretical maximum and minimum oxidation state exhibited by the following elements?

a. N	b. Xe	c. Cl	d. Na
e. Se	f. Ca	g. C	h. B

29. Assign oxidation numbers to each of the elements in the following compounds.

a. $CsClO_4$	b. SO_3	c. UF_6	d. XeF_4	e. KNO_3
f. $Al_2(SO_4)_3$	g. CsH	h. $Na_2Cr_2O_7$	i. OsO_4	j. $(NH_4)_2CO_3$
k. $BaSe$	l. S_8	m. Mg_3UO_6	n. NO_2^+	o. SrO_2
p. XeO_6^{-4}	q. $S_2O_7^{-2}$	r. AsH_3		

30. Identify the following changes as either oxidation or reduction:

a. MnO_2 to MnO_4^-	b. BiO_3^- to Bi^{+3}	c. SO_2 to SO_3
d. OCl^- to ClO_3^-	e. N_2O_4 to N_2O	f. H_2O_2 to H_2O

31. What are the oxidizing agent (oxidant) and the reducing agent (reductant) the followingequations?

a. $Cl_2 + 2\ Br^- \longrightarrow 2\ Cl^- + Br_2$

b. $2\ NO_2 + 7\ H_2 \longrightarrow 2\ NH_3 + 4\ H_2O$

c. $5\ SO_3^{-2} + 2\ MnO_4^- + 6\ H_3O^+ \longrightarrow 5\ SO_4^{-2} + 2\ Mn^{+2} + 9\ H_2O$

d. $2\ Cr(OH)_3 + 3\ ClO^- + 4\ OH^- \longrightarrow 2\ CrO_4^{-2} + 3\ Cl^- + 5\ H_2O$

e. $Cl_2 + 2\ H_2O \longrightarrow HClO + H_3O^+ + Cl^-$

32. Consider the electrolysis of a 1M $CuCl_2$ solution. As it proceeds, you would make these observations:

    (1) The original blue-green color of the solution would gradually fade.

    (2) A shiny light-brown metallic material would deposit on the surface of the cathode.

    (3) A strong-smelling (odor of bleach!) greenish-yellow gas would be formed and discharged at the surface of the anode.

Write the equations for the two half-reactions and the equation for the overall reaction.

    (Hint: aqueous $CuCl_2$ is best inventoried as $Cu(H_2O)_6^{+2}$ and Cl^-.)
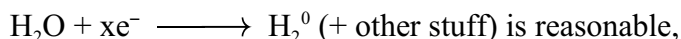
DETERMINING THE PRODUCTS OF REDOX REACTIONS

Suppose we add a bit of K to a few hundred mL of distilled H_2O which results in the production of a gas and yields a solution which was strongly conducting and which turns red litmus to blue. Also, recall that this reaction is an example of redox (i.e., electrons are interchanged).

To "write the equation," what questions might a chemist ask? Or, better yet, what might you as a neophyte chemist ask in conjunction with information with which you are already familiar?

   a.   What might the gas be? H_2? O_2? Both? Are there any other reasonable possibilities?

   b.   The resulting solution conducts, . . . therefore . .? Ions must have been produced!

   c.   What are the ions? Recall that K is a notoriously good e^- "giver-upper"; i.e., K is a dandy reducer. This makes K^+ a very good bet!

   > And, since positive (K^+) ions were produced, it follows that negative ions were also produced. Hence, H_2O (nothing else present initially) must have consumed the e^-'s from the oxidation of K. How about OH^-? Will OH^- turn red litmus blue?

   d.   Let's return to the gas to see if we can decide exactly what it is. Examine H_2O with respect to the oxidation states of the constituent atoms, viz. H^+ and O^{-2}. In H_2 and O_2, the oxidation states for H and O are zero, respectively. Hence it follows that the gaseous product <u>must</u> be H_2! That is, if H_2O consumes electrons (as it does/has in this case), one (or more) of its constituent elements must have been reduced. So . . .
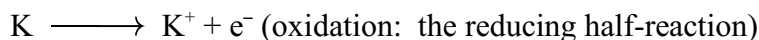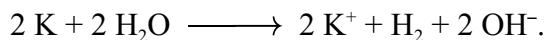
   $$H_2O + xe^- \longrightarrow H_2^0 \text{ (+ other stuff) is reasonable,}$$

   whereas

   $$H_2O + ye^- \longrightarrow O_2^0 \text{ (+ other stuff) is \underline{not} reasonable.}$$
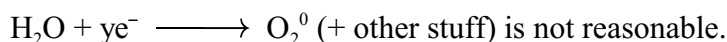
   (Oxygen in H_2O has an oxidation state of -2 and therefore, must **lose** electrons to get to O_2)

   Therefore, the appropriate half-reactions are:

   $$K \longrightarrow K^+ + e^- \text{ (oxidation: the redu\underline{cing} half-reaction)}$$

   $$2 H_2O + 2 e^- \longrightarrow H_2 + 2 OH^- \text{ (reduction: the oxidi\underline{zing} half-reaction)}$$

   . . . and the net reaction is . . .

   $$2 K + 2 H_2O \longrightarrow 2 K^+ + H_2 + 2 OH^-.$$

   Do you see why $K + 2 H_2O \longrightarrow K^+ + H_2 + 2 OH^-$ can <u>not</u> be correct? (Charge balance!)

   Of course, if KOH was an insoluble material, we would have observed the formation of a white crystalline solid during the reaction, and we would then have written KOH as a product, not K^+ and OH^-.

33. Consider the observations in the following experiments.

   i. K reacts explosively with H_2O (See discussion above).

   ii. Ca reacts vigorously (but not violently like K) with H_2O to produce the gas and a colorless solution.

   iii. Cu reacts, for all intents and purposes, not at all with H_2O under normal laboratory conditions (What would be the expected products?).

   iv. When a piece of Cu is placed in a 1M $AgNO_3$ solution, the original colorless solution turns a blue-green color as the piece of Cu disappears. A silvery-colored metallic solid is also formed. (See problem 32.)

   With these experimental findings in mind:

   A) Write the equations which correspond to the changes in each of the above reactions and indicate the relative extent to which each occurred.

   B) For each of the equations in A, decide which reducer is the stronger; the reducer on the left side or the reducer on the right side.

   C) For each of the equations in A, decide which oxidizer is the stronger; the oxidizer on the left side or the oxidizer on the right side.

   D) Now prepare a redox table similar to the one presented in class which lists your FIVE reducers and their FIVE conjugate oxidizers. Consult your notes to see how to properly rank them!

34. Complete and balance the following reactions **assuming that the oxidizer ends up at its minimum oxidation state and the reducer ends up with its highest oxidation state.**
Also, label the products as either ionic or molecular.

   a. $Na + I_2$ b. $Cs + S_8$ c. $Mg + P_4$

   d. $Al + O_2$ e. $Be + O_2$ f. $Li + O_2$

   g. $C + O_{2(xs)}$ h. $Zn + Br_2$ i. $Sc + O_2$

   j. $K + H_2$ k. $Ba + H_2$ l. $P_4 + F_2$

   m. $H_2 + Br_2$ n. $H_2 + S8$ o. $H_2 + O_2$

35. A method for the preparation of O_2 in the lab is via the thermal decomposition of KNO_3. The products of this reaction are KNO_2 and O_2. Write the equation. Identify the element which has been reduced, and the element which has been oxidized.

**QUESTIONS ABOUT COLLIGATIVE PROPERTIES OF SOLUTIONS**

36. Express Raoult's law in words. Is Raoult's law valid for a solution of a volatile solute? Explain.

37. What are the most important differences between the phase diagram of a pure solvent and the solution of a non-volatile solute in this solvent?

38. Calculate the vapor pressure of a solution of 44.0 g glycerol (considered to be non-volatile) which has the formula of $C_3H_8O_3$, in 500.0 g water at 25 °C. The vapor pressure of pure water at 25 °C is 23.8 torr.

39. What is the freezing point of a 0.111 m urea (CH_4N_2O) solution in water?

40. The freezing point of benzene is 5.50 °C. What is the freezing point of a solution of 6.41 g naphthalene (C_8H_{10}) in 469 g benzene? (K_f for benzene is -5.12 °C/m)

41. The normal boiling point of ethanol is 78.50 °C. What is the boiling point of a solution of 3.43 g of the nonvolatile vanillin ($C_8H_8O_3$) in 50.0 g ethanol? (K_b of ethanol = 1.22 °C/m).

42. Rank the following aqueous solutions; i) 0.100 m $NaNO_3$, ii) 0.200 m sucrose, iii) 0.100 m $CaCl_2$
    - in order of increasing,

    a) vapor pressure   b) boiling point   c) freezing point.

43. The freezing point depression (ΔT_f) of a solution of 0.937 g caffeine in 100 g phenol (C_6H_6O) is −0.357 °C. If the K_f for phenol is −7.40 °C/m, what is the apparent molar mass of caffeine.

44. At equilibrium, do a liquid solution and the vapor above it have the same composition? Explain.

45. A solution is composed of 1.50 moles of CH_2Cl_2 and 1.00 moles of CCl_4 at 23.5 °C. At 23.5 °C, the vapor pressures of pure CH_2Cl_2 and CCl_4 are 352 torr and 118 torr respectively.

    a) What are the partial pressures and the total vapor pressure above this solution?

    b) What is the composition of the vapor above the solution in term of mole fractions?

46. a) At 50 °C, Methanol has a vapor pressure of 400 torr and water has a vapor pressure of 92.5 torr. Sketch a graph of the vapor pressure at 50 °C vs mole fraction for the two components and the total vapor pressure. Finish labeling the x-axis in terms mole fractions of the components.

VP_{water} VP_{meth}

X
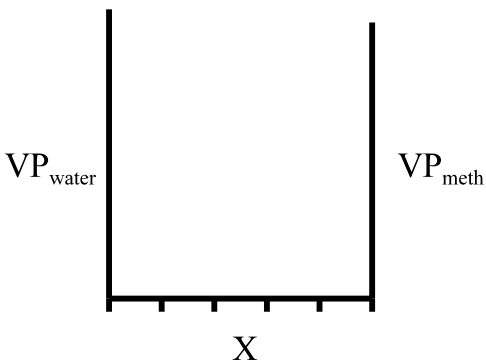
b) Given that methanol has a normal boiling point of 65 °C, sketch a graph of temperature vs mole fraction for the liquid and vapor for a mixture of methanol and water. Again, finish labeling the x-axis in terms mole fractions of the components.

T | | T

X
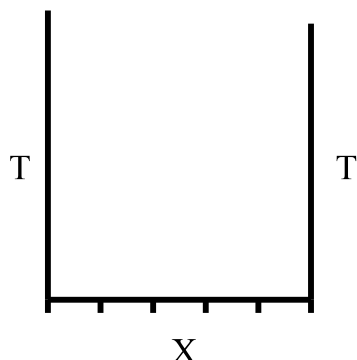
47. Trioxane (NPB = 114.5 °C) has a vapor pressure of 22 torr at 25 °C. Water has a vapor pressure of 23.76 torr. Trioxane and water for an azeotrope which boils at 91.4 °C. The azeotrope has a mole fraction of trioxane equal to 0.32. Sketch an approximate graph of the vapor pressure vs mole fraction for the two components and the total vapor pressure. Finish labeling the x-axis in terms mole fractions of the components. Then sketch a graph of temperature vs mole fraction for the liquid and vapor. Again, finish labeling the x-axis in terms mole fractions of the components.

VP_{water} | $VP_{trioxane}$ T | T

X   X
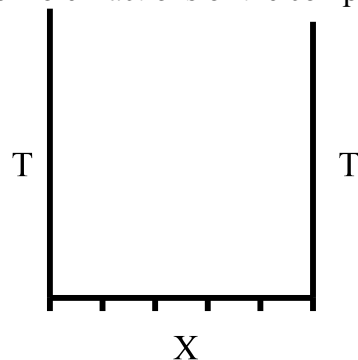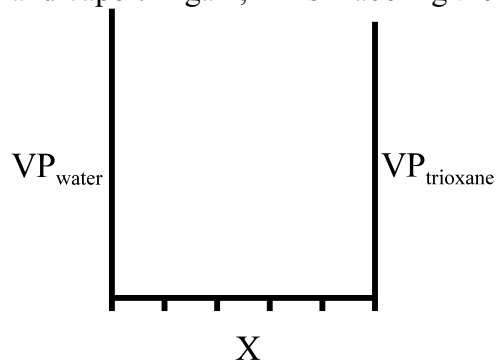
48. Calculate the osmotic pressure produced by a 0.10 M sugar solution at 25 °C.

49. A protein with a large molar mass is dissolved in water at 15 °C and the resulting solution has an osmotic pressure of 11.2 torr. If the solution contains 4.64 g of protein per liter of solution, what is the molar mass of this protein?

Relative Acid/Base Strengths -- in Conjugate Pairs

	Acid	Base	
Strong Acids	$HClO_4$	ClO_4^-	
	H_2SO_4	HSO_4^-	too weak (to act as bases in aqueous sol'n)
	HI	I^-	
	HBr	Br^-	
	HCl	Cl^-	
	HNO_3	NO_3^-	
	H_3O^+	H_2O	
	H_2SO_3	HSO_3^-	
	HSO_4^-	SO_4^{-2}	Weak
	H_3PO_4	$H_2PO_4^-$	Bases
	HNO_2	NO_2^-	
	HF	F^-	
Increasing ACID Strength	$HCOOH$	$HCOO^-$	Increasing BASE Strength
	CH_3COOH	CH_3COO^-	
	$Al(H_2O)_6^{+3}$	$Al(H_2O)_5(OH)^{+2}$	
	H_2CO_3	HCO_3^-	
	H_2S	HS^-	
	$H_2PO_4^-$	HPO_4^{-2}	
Weak Acids	NH_4^+	NH_3	
	HCO_3^-	CO_3^{-2}	
	$CH_3NH_3^+$	CH_3NH_2	
	HPO_4^{-2}	PO_4^{-3}	
	H_2O	OH^-	
too weak (to act as acids in aqueous sol'n)	HS^-	S^{-2}	Strong
	NH_3	NH_2^-	Bases
	OH^-	O^{-2}	