

**QUESTIONS ABOUT LEWIS STRUCTURES**

(Read handout on Drawing Lewis Structures before doing problems below)

- Write Lewis electron structures for the molecules **most likely** to be formed from the simple combination of nonmetals (Note: More than one atom of each element may be required):
  - H, Cl
  - H, S
  - Cl, O
  - N, Br
  - Br, Br
  - C, S
  - P, I
  - C, F
- The following molecules contain one or more multiple bond(s). The sequence of bonding is indicated. Write the correct Lewis structure for each.
  - H, N, N, H
  - S, C, S
  - C, O
  - S, C, O
  - Cl, C, C, Cl
  - H, C, N
- Write ALL acceptable Lewis structures for each of the following molecules or polyatomic ions. Include formal charges where required.
  - $\text{NO}^+$
  - $\text{NO}_2^+$
  - $\text{CO}_2$
  - $\text{C}_6\text{H}_{14}$
  - $\text{NF}_2^-$
  - $\text{COCl}_2$
  - $\text{NH}_2^-$
  - $\text{PH}_3$
  - $\text{C}_3\text{H}_4$
  - $^*\text{H}_2\text{CO}_3$
  - $\text{PF}_4^+$
  - $^*\text{HNO}_2$
  - $^*\text{HOCl}$
  - $\text{CH}_2\text{O}$
  - $\text{C}_2\text{H}_4$
  - $\text{C}_2\text{H}_3\text{F}$
  - $\text{C}_2\text{H}_2\text{F}_2$
  - $\text{C}_2\text{H}_5\text{F}$
  - $\text{C}_2\text{H}_4\text{F}_2$
  - $\text{C}_2\text{H}_6\text{O}$

\* H's are attached to O

**QUESTIONS ABOUT GEOMETRY AND VSEPR**

See handout at the end of this problem set for VSEPR summary.

- For each of the species listed in problem 3, predict the geometry based on VSEPR theory and state whether the species is expected to be polar, non-polar or whether the idea doesn't apply?
- Each of the following molecules only contain one covalent bond. Therefore, the individual bond polarity is indicative of net molecular polarity. List the following molecules in order of increasing molecular polarity: I-Cl, Br-Cl, Cl-Cl, Br-F, Cl-F

**QUESTIONS INVOLVING SOLUTIONS**

- In which physical state (solid, liquid, or gas) is it easiest to carry out chemical reactions? Explain.
- What is the definition of the word "solution?"
- What are the components of a solution? How are they distinguished?
- Why are most chemical reactions carried out in liquid solution?

10. Generally, what is the most “convenient” concentration unit for chemists to use? Why?
11. What is the definition of “Molarity?”
12. What is the molarity of sugar,  $C_{12}H_{22}O_{11}$ , if 53.5 g of sugar are dissolved to give 746 mL of solution?
13. What is the molarity of KCl if 1.45 g of KCl are dissolved to give 50.0 mL of solution?
14. How many grams of  $NaNO_3$  are there in 75.0 mL of 1.00 M  $NaNO_3$  solution?
15. Discuss an experimental method to determine whether or not a compound is molecular or ionic.
16. Consider the formulas: HOH, NaOH, HCl, NaCl. Which are predicted to be molecular materials? Which are expected to be ionic materials? Explain.
17. What is unusual about the composition of salts such as  $NH_4Cl$  or  $(NH_4)_2SO_4$ ?
18. For solutions, what are electrolytes? What are nonelectrolytes?
19. What is necessary for a substance to conduct electricity? Explain.
20. Why does solid NaCl not conduct electricity but an aqueous solution of NaCl does?
21. Give all possible ways one can get ions into solution. Explain!
22. If a solute is known to be a nonelectrolyte in solution, what, if anything, can one infer about the type of bonding in the pure solute?
23. If a solute is known to be an electrolyte in solution, what, if anything, can one infer about the type of bonding in the pure solute?
24. The process 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  $(NH_4)_2SO_4$

### QUESTIONS ABOUT ACIDS AND BASES

25. What is the definition of a Brønsted-Lowry acid? What is the definition of a Brønsted-Lowry base?
26. 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.
27. 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.
28. What are the products of any acid/base reaction?

29. What are the conjugate acids of the following species?
- a)  $\text{H}_2\text{O}$                       b)  $\text{OH}^-$                       c)  $\text{NH}_3$                       d)  $\text{X}^-$                       e)  $\text{HX}$
30. What are the conjugate bases of the following species?
- a)  $\text{H}_2\text{O}$                       b)  $\text{OH}^-$                       c)  $\text{NH}_3$                       d)  $\text{HX}$                       e)  $\text{H}_3\text{O}^+$
31. In terms of their reaction with water, how are strong acids defined? How are weak acids defined?
32. Write the equation for the reaction of a strong acid,  $\text{HX}$ , with water. Write the equation for the reaction of a weak acid,  $\text{HX}$ , with water. What is the difference between the two equations? Explain.
33. What are the six common strong acids? Memorize them! How then, are all other acids classified?
34. Remember: An inventory is a list of the formulas and concentrations of the solute ions and molecules present in appreciable amounts in a solution. What is the inventory of 1M  $\text{HCl}$ ? What is the inventory of a 1 M solution of any strong acid,  $\text{HX}$ ? A 1 M solution of any weak acid,  $\text{HY}$ ?
35. Explain why liquid  $\text{HCl}$  does not conduct electricity but a 1M  $\text{HCl}$  solution does conduct.
36. How would the conductivity of a 1M  $\text{HCl}$  solution differ from the conductivity of a 1M  $\text{HC}_2\text{H}_3\text{O}_2$  solution? Explain.
37. If the conductivity of an aqueous solution of acid  $\text{HZ}$  were such that the 150 watt bulb lit brightly while the aqueous solution of acid  $\text{HY}$  lit only the 7.5 watt bulb dimly, what conclusion can one safely draw from these observations about the relative acid strengths of  $\text{HZ}$  and  $\text{HY}$ ? Explain.
38. In terms of their reaction with water, how are strong bases defined? How are weak bases defined?
39. Write the equation for the reaction of a strong base,  $\text{B}$ , with water. Write the equation for the reaction of a weak base,  $\text{B}$ , with water. What is the difference between the two equations? Explain.
40. What are the ten common strong bases? Memorize them! How then, are all other bases classified?
41. What is the inventory of a 1M  $\text{Na}_2\text{O}$  solution? What is the inventory of a 1 M solution of any strong base? A 1 M solution of any weak base?
42. Explain why liquid  $\text{NH}_3$  does not conduct electricity but a 1M  $\text{NH}_3$  solution does conduct (slightly).
43. 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.
44. If the conductivity of an aqueous solution of base  $\text{Z}$  was such that the 7.5 watt bulb lit brightly while the aqueous solution of base  $\text{Y}$  lit only the 7.5 watt bulb dimly, what conclusion can one safely draw from these observations about the relative base strengths of  $\text{Z}$  and  $\text{Y}$ ? Explain.

45. 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.

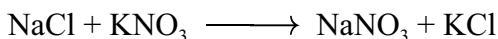
- A. Suppose that you are in a laboratory and are directed to the reagent shelf, whereupon you observe two large bottles, each of which contains a clear, colorless, homogenous liquid. One bottle bears the label 0.5 M  $\text{Na}_2\text{CO}_3$  and the other, 0.5 M  $\text{CaCl}_2$ . Now, you are told (in case you might not know) that both  $\text{Na}_2\text{CO}_3$  and  $\text{CaCl}_2$  are white, crystalline, ionic solids under standard laboratory conditions.

Your next direction is to mix two mL of the 0.5 M  $\text{Na}_2\text{CO}_3$  with two mL of the 0.5 M  $\text{CaCl}_2$ . 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?

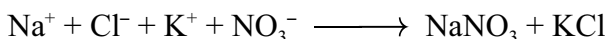
Now, if you're careful, you'll back off, don your thinking cap, and recognize that from this very brief laboratory experience you're already in a position to assemble quite a bit of chemical information.



Consequently, to write something like . . .



or

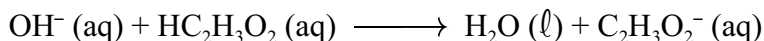


would be utterly ridiculous as no such chemical changes (reactions) would take place upon mixing these solutions. Therefore, the logical consequence of all this is to realize that equations are to be written only for situations wherein there is evidence that a chemical change has indeed taken place.

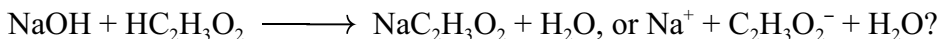
- B. Recall the laboratory experiment, "Solution Stoichiometry." In this experiment, you were formally introduced to "concentration." Specifically, you dealt with the "moles per liter" (or "molar," abbreviated as M) concentration of a solution of sodium hydroxide (NaOH). Molar (M) means the amount of 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  $\text{HC}_2\text{H}_3\text{O}_2$  in a vinegar solution by reacting the  $\text{HC}_2\text{H}_3\text{O}_2$  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  $\text{HC}_2\text{H}_3\text{O}_2$  in the 25.00 mL of the vinegar sample." This is because  $\text{OH}^-$  and  $\text{HC}_2\text{H}_3\text{O}_2$  combine chemically on a mole for mole basis.

The correct equation shows this is

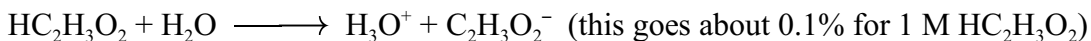


Why not?

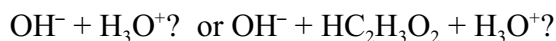


Again, what is NaOH? It is a white, crystalline, hygroscopic solid under standard laboratory conditions. Did you add such a material to the vinegar solution? No! You added a solution which contained  $\text{Na}^+$  and  $\text{OH}^-$ . And when you added this solution to the vinegar, did any white solids form? No again! Therefore, since  $\text{NaC}_2\text{H}_3\text{O}_2$  is a white crystalline solid under normal lab conditions, we do not write  $\text{NaC}_2\text{H}_3\text{O}_2$  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  $\text{H}_2\text{O}$ ) whose formula was best represented as  $\text{HC}_2\text{H}_3\text{O}_2$ . That is, if ionic solids dissolve into simpler ingredients (the constituent ions), might not  $\text{HC}_2\text{H}_3\text{O}_2$  dissolve in water into simpler ingredients? Yes, this is possible! And in fact this does occur to a small but measurable extent, when  $\text{HC}_2\text{H}_3\text{O}_2$  is dissolved in  $\text{H}_2\text{O}$ , the transformation is:



and we shall recognize that materials which are capable of giving up  $\text{H}^+$  (proton) in a chemical process are known as acids. Consequently, we see that  $\text{HC}_2\text{H}_3\text{O}_2$  is an acid ( $\text{H}_2\text{O}$  is too!). So when we wrote the titration equation, why didn't we write



The answer to this is simply that because there is such a very small  $[\text{H}_3\text{O}^+]$  in the vinegar solution, there is no meaningful point in including  $\text{H}_3\text{O}^+$  in the titration equation. That is, the primary reaction which occurs when we add  $\text{NaOH}$  solution to vinegar is between the base  $\text{OH}^-$  and the acid  $\text{HC}_2\text{H}_3\text{O}_2$ .

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  $\text{H}_2\text{O}$ , was  $\text{HC}_2\text{H}_3\text{O}_2$  (i.e., **NOT**  $\text{H}_3\text{O}^+$  and  $\text{C}_2\text{H}_3\text{O}_2^-$ )? **See Problem 36.**

### QUESTIONS ON EQUATION WRITING FOR ACID BASE REACTIONS

46. 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  $\text{HCl}$  with 0.1 M  $\text{KOH}$
- b. 0.1 M  $\text{HNO}_3$  with 0.1 M  $\text{NH}_3$
- c. 0.1 M  $\text{H}_2\text{SO}_4$  with 0.1 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- d. 0.1  $\text{NaHSO}_4$  with 0.1 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- e. 0.1 M  $\text{NH}_4\text{Cl}$  with 0.1 M  $\text{NaOH}$
- f. 0.1 M  $\text{NaHCO}_3$  with 0.1 M  $\text{LiOH}$
- g. 0.1 M  $\text{HC}_2\text{H}_3\text{O}_2$  with 0.1 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- h. 0.1 M  $\text{HC}_2\text{H}_3\text{O}_2$  with 0.1 M  $\text{MgSO}_4$  (NOTE:  $\text{Mg}(\text{H}_2\text{O})_6^{+2}$  is a weaker acid than  $\text{HC}_2\text{H}_3\text{O}_2$ )
- i. 0.1 M  $\text{HC}_2\text{H}_3\text{O}_2$  with  $\text{H}_2\text{O}$  (i.e., vinegar is diluted)
- j. Pure liquid  $\text{HNO}_3$  with pure solid  $\text{NaOH}$

# QUESTIONS ON OXIDATION AND REDUCTION

47. What is the definition of oxidation? What is the definition of reduction?
48. What is the definition of an oxidizer? What is the definition of a reducer?
49. What are the products of any redox reaction?
50. What is the relationship, if any, between the concepts of oxidation state and formal charge? Explain.
51. What is the theoretical maximum and minimum oxidation state exhibited by each of the following elements?
- |       |       |       |       |
|-------|-------|-------|-------|
| a. N  | b. Xe | c. Cl | d. Na |
| e. Se | f. Ca | g. C  | h. B  |
52. Assign oxidation numbers to each of the elements in the following compounds.
- |  |   |  |
|--|---|--|
| a. CsClO <sub>4</sub>                              | b. SO <sub>3</sub>                                | c. UF <sub>6</sub>                                 |
| d. XeF <sub>4</sub>                                | e. KNO <sub>3</sub>                               | f. Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> |
| g. CsH   | h. Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> | i. OsO <sub>4</sub>                                |
| j. (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> | k. BaSe   | l. S <sub>8</sub>                                  |
| m. Mg <sub>3</sub> UO <sub>6</sub>                 | n. NO <sub>2</sub> <sup>+</sup>                   | o. SrO <sub>2</sub>                                |
| p. XeO <sub>6</sub> <sup>-4</sup>                  | q. S <sub>2</sub> O <sub>7</sub> <sup>-2</sup>    | r. AsH <sub>3</sub>                                |
53. Identify the following changes as either oxidation or reduction:
- |  |  |  |
|--|--|--|
| a. MnO <sub>2</sub> to MnO <sub>4</sub> <sup>-</sup> | b. BiO <sub>3</sub> <sup>-</sup> to Bi <sup>+3</sup> | c. SO <sub>2</sub> to SO <sub>3</sub>                |
| d. OCl <sup>-</sup> to ClO <sub>3</sub> <sup>-</sup> | e. N <sub>2</sub> O <sub>4</sub> to N <sub>2</sub> O | f. H <sub>2</sub> O <sub>2</sub> to H <sub>2</sub> O |
54. What is the oxidizing agent (oxidant) and the reducing agent (reductant) in each of the following equations?
- $\text{Cl}_2 + 2 \text{Br}^- \longrightarrow 2 \text{Cl}^- + \text{Br}_2$
  - $2 \text{NO}_2 + 7 \text{H}_2 \longrightarrow 2 \text{NH}_3 + 4 \text{H}_2\text{O}$
  - $5 \text{SO}_3^{-2} + 2 \text{MnO}_4^- + 6 \text{H}_3\text{O}^+ \longrightarrow 5 \text{SO}_4^{-2} + 2 \text{Mn}^{+2} + 9 \text{H}_2\text{O}$
  - $2 \text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3 + 3 \text{ClO}^- + 4 \text{OH}^- \longrightarrow 2 \text{CrO}_4^{-2} + 3 \text{Cl}^- + 11 \text{H}_2\text{O}$
  - $\text{Cl}_2 + 2 \text{H}_2\text{O} \longrightarrow \text{HClO} + \text{H}_3\text{O}^+ + \text{Cl}^-$
55. Consider the electrolysis of a 1M CuCl<sub>2</sub> 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<sub>2</sub> is best inventoried as Cu(H<sub>2</sub>O)<sub>6</sub><sup>+2</sup> and Cl<sup>-</sup>.)

## DETERMINING THE PRODUCTS OF REDOX REACTIONS

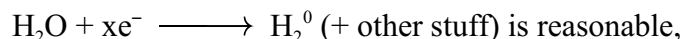
Suppose we add a bit of K to a few hundred mL of distilled H<sub>2</sub>O which results in the production of a gas and yields a solution which was strongly conducting and which turns red litmus to blue. Also, recall that this reaction is an example of redox (i.e., electrons are interchanged).

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?

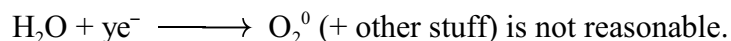
- What might the gas be? H<sub>2</sub>? O<sub>2</sub>? Both? Are there any other reasonable possibilities?
- The resulting solution conducts, . . . therefore . . .? Ions must have been produced!
- What are the ions? Recall that K is a notoriously good e<sup>-</sup> "giver-upper"; i.e., K is a dandy reducer. This makes K<sup>+</sup> a very good bet!

And, since positive (K<sup>+</sup>) ions were produced, it follows that negative ions were also produced. Hence, H<sub>2</sub>O (nothing else present initially) must have consumed the e<sup>-</sup>'s from the oxidation of K. How about OH<sup>-</sup>? Will OH<sup>-</sup> turn red litmus blue?

- Let's return to the gas to see if we can decide exactly what it is. Examine H<sub>2</sub>O with respect to the oxidation states of the constituent atoms, viz. H<sup>+</sup> and O<sup>-2</sup>. In H<sub>2</sub> and O<sub>2</sub>, the oxidation states for H and O are zero, respectively. Hence it follows that the gaseous product must be H<sub>2</sub>! That is, if H<sub>2</sub>O consumes electrons (as it does/has in this case), one (or more) of its constituent elements must have been reduced. So . . .



whereas

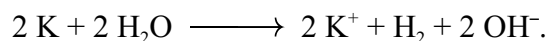


(Oxygen in H<sub>2</sub>O has an oxidation state of -2 and therefore, must LOSE electrons to get to O<sub>2</sub>)

Therefore, the appropriate half-reactions are:



. . . and the net reaction is . . .



Do you see why  $\text{K} + 2 \text{H}_2\text{O} \longrightarrow \text{K}^+ + \text{H}_2 + 2 \text{OH}^-$  can not be correct? (No 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<sup>+</sup> and OH<sup>-</sup>.

56. Consider the observations in the following experiments.

- i. K reacts explosively with  $\text{H}_2\text{O}$  (See previous discussion on determining products).
- ii. Ca reacts vigorously (but not violently like K) with  $\text{H}_2\text{O}$  to produce the gas and a colorless solution.
- iii. Cu reacts, for all intents and purposes, not at all with  $\text{H}_2\text{O}$  under normal laboratory conditions (What would be the expected products?  $\text{Cu}(\text{H}_2\text{O})_6^{+2}$ ,  $\text{OH}^-$ ,  $\text{H}_2$ ).
- iv. When a piece of Cu is placed in a 1M  $\text{AgNO}_3$  solution, the original colorless solution turns a blue-green color as the piece of Cu disappears. A silvery-colored metallic solid is also formed.

**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 list them!

57. 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. $\text{Na} + \text{I}_2$             | b. $\text{Cs} + \text{S}_8$  | c. $\text{Mg} + \text{P}_4$  |
| d. $\text{Al} + \text{O}_2$             | e. $\text{Be} + \text{O}_2$  | f. $\text{Li} + \text{O}_2$  |
| g. $\text{C} + \text{O}_{2(\text{xs})}$ | h. $\text{Zn} + \text{Br}_2$ | i. $\text{Sc} + \text{O}_2$  |
| j. $\text{K} + \text{H}_2$              | k. $\text{Ba} + \text{H}_2$  | l. $\text{P}_4 + \text{F}_2$ |
| m. $\text{H}_2 + \text{Br}_2$           | n. $\text{H}_2 + \text{S}_8$ | o. $\text{H}_2 + \text{O}_2$ |



# Relative Acid/Base Strengths -- in Conjugate Pairs

	Acid	Base	
	HClO <sub>4</sub>	ClO <sub>4</sub> <sup>-</sup>	} too weak (to act as bases in aqueous sol'n)
	H <sub>2</sub> SO <sub>4</sub>	HSO <sub>4</sub> <sup>-</sup>	
Strong	HI	I <sup>-</sup>	
Acids	HBr	Br <sup>-</sup>	
	HCl	Cl <sup>-</sup>	
	HNO <sub>3</sub>	NO <sub>3</sub> <sup>-</sup>	
	H <sub>3</sub> O <sup>+</sup>	H <sub>2</sub> O	
	H <sub>2</sub> SO <sub>3</sub>	HSO <sub>3</sub> <sup>-</sup>	
	HSO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	Weak
	H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	Bases
	HNO <sub>2</sub>	NO <sub>2</sub> <sup>-</sup>	
	HF	F <sup>-</sup>	
	HCOOH	HCOO <sup>-</sup>	
	CH <sub>3</sub> COOH	CH <sub>3</sub> COO <sup>-</sup>	
	Al(H <sub>2</sub> O) <sub>6</sub> <sup>+3</sup>	Al(H <sub>2</sub> O) <sub>5</sub> (OH) <sup>+2</sup>	
	H <sub>2</sub> CO <sub>3</sub>	HCO <sub>3</sub> <sup>-</sup>	
	H <sub>2</sub> S	HS <sup>-</sup>	
	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>-2</sup>	
Weak	NH <sub>4</sub> <sup>+</sup>	NH <sub>3</sub>	
Acids	HCO <sub>3</sub> <sup>-</sup>	CO <sub>3</sub> <sup>-2</sup>	
	CH <sub>3</sub> NH <sub>3</sub> <sup>+</sup>	CH <sub>3</sub> NH <sub>2</sub>	
	HPO <sub>4</sub> <sup>-2</sup>	PO <sub>4</sub> <sup>-3</sup>	
	H <sub>2</sub> O	OH <sup>-</sup>	
	HS <sup>-</sup>	S <sup>-2</sup>	} Strong Bases
too weak (to act as acids in aqueous sol'n)	NH <sub>3</sub>	NH <sub>2</sub> <sup>-</sup>	
	OH <sup>-</sup>	O <sup>-2</sup>	