

QUESTIONS ABOUT LEWIS STRUCTURES

1.	a)	$\text{H}-\ddot{\text{Cl}} $	b)	$\text{H}-\ddot{\text{S}}-\text{H}$	c)	$ \ddot{\text{Cl}}-\ddot{\text{O}}-\ddot{\text{Cl}} $	d)	$\begin{array}{c} \ddot{\text{Br}} \\ \\ \ddot{\text{Br}}-\ddot{\text{N}}-\ddot{\text{Br}} \\ \end{array}$
	e)	$ \ddot{\text{Br}}-\ddot{\text{Br}} $	f)	$\ddot{\text{S}}=\text{C}=\ddot{\text{S}}$	g)	$\begin{array}{c} \ddot{\text{I}} \\ \\ \ddot{\text{I}}-\ddot{\text{P}}-\ddot{\text{I}} \\ \end{array}$	h)	$\begin{array}{c} \ddot{\text{F}} \\ \\ \ddot{\text{F}}-\ddot{\text{C}}-\ddot{\text{F}} \\ \ddot{\text{F}} \\ \end{array}$

2.	a)	$\text{H}-\ddot{\text{N}}=\ddot{\text{N}}-\text{H}$	b)	$\ddot{\text{S}}=\text{C}=\ddot{\text{S}}$	c)	$ \ddot{\text{C}}\equiv\text{O}^+ $
	d)	$\ddot{\text{S}}=\text{C}=\ddot{\text{O}}$	e)	$ \ddot{\text{Cl}}-\text{C}\equiv\text{C}-\ddot{\text{Cl}} $	f)	$\text{H}-\text{C}\equiv\text{N} $

3. Note: Lewis structures are not intended to depict geometry - only electron distributions.
A * by the structure indicate that resonance is present.

a)	$[\text{N}\equiv\text{O}]^+$	b)	$[\ddot{\text{O}}=\text{N}^+=\ddot{\text{O}}]^+$	c)	$ \ddot{\text{O}}=\text{C}=\ddot{\text{O}} $	d1)	$\begin{array}{ccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
d2)	$\begin{array}{ccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ & & & & \text{H} & & \end{array}$	d3)	$\begin{array}{ccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ & & & & \text{H} & & \end{array}$	d4)	$\begin{array}{ccccccc} & & \text{H} & & & & \\ & & & & & & \\ \text{H} & \text{H} & \text{C}-\text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{C}-\text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ & & \text{H} & & & & \end{array}$	d5)	$\begin{array}{ccccccc} & & \text{H} & & & & \\ & & & & & & \\ \text{H} & \text{H} & \text{C}-\text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{C}-\text{H} & \text{H} & \text{H} & & \\ & & & & & & \\ & & \text{H} & & & & \end{array}$
e)	$[\ddot{\text{F}}-\ddot{\text{N}}-\ddot{\text{F}}]^-$	f)	$\begin{array}{c} \ddot{\text{Cl}} \\ \\ \ddot{\text{Cl}}-\ddot{\text{C}}=\ddot{\text{O}} \\ \end{array}$	g)	$[\text{H}-\ddot{\text{N}}-\text{H}]^-$	h)	$\begin{array}{c} \ddot{\text{H}}-\ddot{\text{P}}-\ddot{\text{H}} \\ \\ \ddot{\text{H}} \end{array}$

i1)		i2)		i3)		j)	
k)		l)		m)		n)	
o)		p)		q1)		q2)	
q3)		r)		s1)		s2)	
t1)		t2)					

QUESTIONS ABOUT GEOMETRY AND VSEPR

4. a) linear on both N and O: DNA. b) linear on N: DNA.
 c) linear on C: Nonpolar. d) tetrahedral on all C's in every isomer: Polar.
 e) angular on N: DNA. f) trigonal planar on C: Polar.
 g) angular on N: DNA. h) trigonal pyramidal on P: Polar.
 i1) trigonal planar/linear/trigonal planar: Nonpolar. i2) linear/linear/tetrahedral: Nonpolar
 i3) trigonal planar on 2 C's and tetrahedral on 1 C: Polar.
 j) trigonal planar on C and angular on O: Polar. k) tetrahedral on P: DNA.
 l) angular on both N and O: Polar. m) angular: Polar.
 n) trigonal planar: Polar. o) trigonal planar on both C: Nonpolar.
 p) trigonal planar on both C's: Polar. q1) trigonal planar on both C's: Polar
 q2) trigonal planar on both C's: Nonpolar q3) trigonal planar on both C's: Polar
 r) tetrahedral on both C's: Polar. s1 & s2) tetrahedral on both C's: Polar.
 t1 & t2) tetrahedral on both C's and angular on O: Polar.

5. Since these molecules are diatomic, the bond polarity is equal to the overall molecular polarity.

BOND	I—Cl	Br—Cl	Cl—Cl	Br—F	Cl—F
EN of Atoms	2.5 , 3.0	2.8 , 3.0	3.0 , 3.0	2.8 , 4.0	3.0 , 4.0
$\Delta(\text{EN})$	0.5	0.2	0.0	1.2	1.0
Polarity of					
Bonds or	Cl—Cl	Br—Cl	I—Cl	Cl—F	Br—F
Molecules	<	<	<	<	

QUESTIONS INVOLVING SOLUTIONS

6. The liquid state is usually the easiest state in which to carry out reactions.

Physical State

Advantages

Disadvantages

Gas

Particles in rapid motion. Therefore, particle mix and react rapidly.

Gases occupy large volumes. Special container needed to contain gases.

Solid

Solids occupy small volumes. No special container needed.

Particle movement nearly absent. Therefore, reaction very slow.

Liquid

Particles in motion. Therefore, particles mix and react reasonably fast. Volumes occupied by liquids are almost as small as solids. No special equipment needed.

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7. A solution is defined as a **homogeneous mixture**. This definition does not specify the physical state. Therefore, a solution may be a solid, liquid or a gas mixture (as long as it is homogeneous).
8. The two components of a solution are the solvent and the solute. The distinction between them is arbitrary. The distinction is often based on the relative amounts of the two components with the solvent being present in a larger amount. Sometimes, the difference is based on the final physical state of the mixture. For example, if one of the components is a solid and the other a liquid then the distinction is made based on the state of the mixture. If the mixture is a liquid then the solvent is considered to be the liquid. If the mix is a solid then the solid is the solvent.
9. Reactions are generally carried out in the liquid state for the advantages listed in problem 6. If one or more of the reactants are gases or solids, they are converted into a **liquid solution** by dissolving them into a liquid solvent.
10. Since chemicals combine by number and not by mass it follows that one would wish to determine the moles of the various reactants present in the reaction. Furthermore, since the most convenient property to measure for a liquid is volume (see reasons for using liquid solutions above), it follows that one would need a conversion factor to convert between the volume of liquid used and the moles of solute dissolved in the solution. Therefore, molarity (M) is the most convenient concentration unit for chemists.

$$11. \text{Molarity (M)} \equiv \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$12. M = \frac{53.5 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}}{746 \text{ mL soln}} \times \frac{1 \text{ mole C}_{12}\text{H}_{22}\text{O}_{11}}{342.299 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1 \text{ mL soln}}{10^{-3} \text{ L soln}} = 0.210 \text{ M C}_{12}\text{H}_{22}\text{O}_{11}$$

$$13. M = \frac{1.45 \text{ g KCl}}{50.0 \text{ mL soln}} \times \frac{1 \text{ mole KCl}}{74.551 \text{ g KCl}} \times \frac{1 \text{ mL soln}}{10^{-3} \text{ L soln}} = 0.389 \text{ M KCl}$$

$$14. g = \frac{84.9947 \text{ g NaNO}_3}{1 \text{ mol NaNO}_3} \times \frac{1.00 \text{ mole NaNO}_3}{\text{L soln}} \times \frac{10^{-3} \text{ L soln}}{1 \text{ mL soln}} \times 75.0 \text{ mL soln} = 6.37 \text{ g NaNO}_3$$

15. The classification of a sample as ionic or molecular is not always easy. It is often done through a series of observations. The first step is to determine the physical state of the pure substance. If the pure substance is a gas or liquid under normal laboratory conditions, then this is considered as proof that it is a molecular compound. However, if it is a solid, the sample can still be either ionic or molecular. At this point the chemist usually resorts to conductivity measurements. If the sample is soluble in water and the resulting solution does not conduct, this is evidence that it is molecular. If the sample does conduct, it may still be either ionic or molecular (see problem 21 below). At this point the chemist might melt the sample (if possible) and determine if the melt is conductive. If it does, it is classified as ionic and if it is non-conductive it is considered molecular.

16. H₂O and HCl are expected to be molecular compounds as they are composed of all nonmetal atoms. NaOH and NaCl are expected to be ionic since they are composed of metal and nonmetal atoms.

17. The fact that they are ionic is remarkable since they are composed of all nonmetal atoms. Each compound contains the ammonium ion NH₄⁺, a cation made up of nonmetal elements only and not the usual metal atoms that typically form cations.

18. **Electrolytes** are substances that conduct electricity when dissolved in solution.

Nonelectrolytes are substances that do not conduct electricity when dissolved in solution.

19. Since current electricity is simply the flow of charge a **sample must contain charges that can flow**.

20. A sample of solid NaCl does not conduct electricity because even though the sample does contain charges (the ions) those charges (the ions) cannot move (or flow). In an aqueous solution of NaCl, the charge or ions are free to flow in the liquid state (the water solution) and therefore the solution is an excellent conductor of electricity.

21. There are two basic ways ions can get into solution, by dissociation and by ionization.

Dissociation refers the process in which the ions dis-associate from each other as they dissolve into a liquid solution.

Ionization refers to the process of reaction between chemical entities to create ions.

22. Since the solute has actually dissolved into the solution then the solute particles must be separated and mobile. If the solution **does not** conduct electricity then the solution **does not** contain ions. Thus only molecules exist in the solution and therefore the solute must be molecular in nature.
23. Since the solute has actually dissolved into the solution then the solute particles must be separated and mobile. If the solution **does** conduct electricity then the solution **does** contain mobile ions. However, this does not mean that the solute must be ionic. It is true that IF an ionic solute does dissolve then mobile ions will be produced and the resulting solution will conduct electricity. However, it is possible for a reaction to occur between a molecular solute and a molecular solvent to create ions (see Ionization in problem 21) and since this solution would also contain mobile ions then this solution would conduct electricity too. Thus if all we know is that a solution conducts electricity we cannot tell if the solute is ionic or molecular in nature.
24. a) $[\text{Na}^+] = 0.25 \text{ M}$, $[\text{Cl}^-] = 0.25 \text{ M}$
 b) $[\text{Ca}^{+2}] = 0.50 \text{ M}$, $[\text{NO}_3^-] = 1.0 \text{ M}$
 c) $[\text{NH}_4^+] = 0.30 \text{ M}$, $[\text{SO}_4^{-2}] = 0.15 \text{ M}$

QUESTIONS ABOUT ACIDS AND BASES

25. A Brønsted-Lowry **acid** is defined as a proton (H^+) donor.
 A Brønsted-Lowry **base** is defined as a proton (H^+) acceptor.
26. In order to function as a proton (H^+) donor the species must have at least one H in the formula.
27. 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^+).
28. 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^+ .
29. a. H_3O^+ b. H_2O c. NH_4^+ d. HX e. H_2X^+
30. a. OH^- b. O^{-2} c. NH_2^- d. X^- e. H_2O
31. 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**.
32. Reaction of a strong acid and water: $\text{HX} + \text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+ + \text{X}^-$
 Reaction of a weak acid and water: $\text{HX} + \text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+ + \text{X}^-$
- 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 30).

33. The six common strong acids are: HCl, HBr, HI, HNO₃, H₂SO₄, and HClO₄. The other acids are classified as weak acids.

34. The inventory of 1 M HCl is $[H_3O^+] = 1\text{ M}$ and $[Cl^-] = 1\text{ M}$.

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

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

35. 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.

36. Although HCl and HC₂H₃O₂ both react as acids with water and the initial amount of HCl and HC₂H₃O₂ 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 contains many ions to support conductivity. On the other hand, HC₂H₃O₂ 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 HC₂H₃O₂ is a poor conductor of electricity.

37. 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.

38. 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**.

39. 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 37).

40. 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.

41. The inventory of 1 M Na_2O is $[\text{Na}^+] = 2 \text{ M}$ and $[\text{OH}^-] = 2 \text{ M}$.

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 $[\text{HB}^+] = 1 \text{ M}$ and $[\text{OH}^-] = 1 \text{ M}$.

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

42. 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.

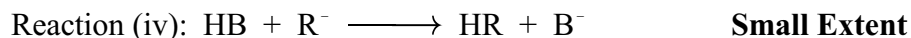
43. The conductivity of solutions of molecular acids and molecular bases is due to these materials reacting with the water solvent to create ions. The stronger the acid (or base), the more conductive the resulting solution will be. Therefore the degree of conductivity gives a measure of the strength 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).
44. As discussed in problem 42 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.

45. A. Reaction (i): $\text{HR} + \text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+ + \text{R}^-$ **Small Extent**
 Reaction (ii): $\text{HR} + \text{G}^- \longrightarrow \text{HG} + \text{R}^-$ **Large Extent**
 Reaction (iii): $\text{HY} + \text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+ + \text{Y}^-$ **Large Extent**
- B. Reaction (i): $\text{H}_3\text{O}^+ > \text{HR}$
 Reaction (ii): $\text{HR} > \text{HG}$
 Reaction (iii): $\text{HY} > \text{H}_3\text{O}^+$
- C. Reaction (i): $\text{R}^- > \text{H}_2\text{O}$
 Reaction (ii): $\text{G}^- > \text{R}^-$
 Reaction (iii): $\text{H}_2\text{O} > \text{Y}^-$

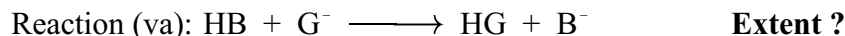
D.

	Acids		Bases	
Stronger	↑ HY	Y ⁻	↓ Weaker	
	H ₃ O ⁺	H ₂ O		
	HR	R ⁻		
Weaker	HG	G ⁻	Stronger	

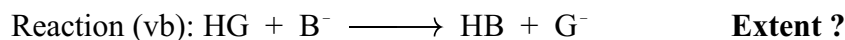
E. The reaction involved is:



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, $\text{B}^- > \text{R}^-$ as bases and $\text{HR} > \text{HB}$ 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.



OR



QUESTIONS ON EQUATION WRITING

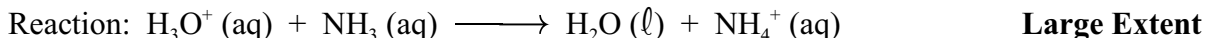
46. a. Inventory of 0.1 M HCl: $[\text{H}_3\text{O}^+] = 0.1 \text{ M}$, $[\text{Cl}^-] = 0.1 \text{ M}$.

Inventory of 0.1 M KOH: $[\text{K}^+] = 0.1 \text{ M}$, $[\text{OH}^-] = 0.1 \text{ M}$.



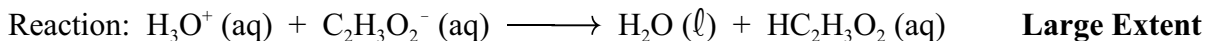
b. Inventory of 0.1 M HNO₃: $[\text{H}_3\text{O}^+] = 0.1 \text{ M}$, $[\text{NO}_3^-] = 0.1 \text{ M}$.

Inventory of 0.1 M NH₃: $[\text{NH}_3] = 0.1 \text{ M}$.



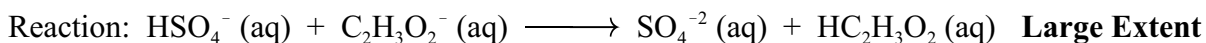
c. Inventory of 0.1 M H₂SO₄: $[\text{H}_3\text{O}^+] = 0.1 \text{ M}$, $[\text{HSO}_4^-] = 0.1 \text{ M}$.

Inventory of 0.1 M NaC₂H₃O₂: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{C}_2\text{H}_3\text{O}_2^-] = 0.1 \text{ M}$.



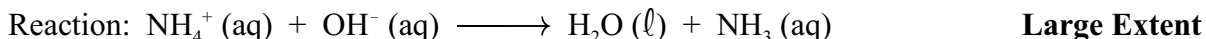
d. Inventory of 0.1 M NaHSO₄: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{HSO}_4^-] = 0.1 \text{ M}$.

Inventory of 0.1 M NaC₂H₃O₂: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{C}_2\text{H}_3\text{O}_2^-] = 0.1 \text{ M}$.



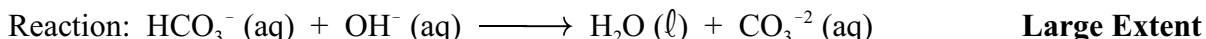
e. Inventory of 0.1 M NH₄Cl: $[\text{NH}_4^+] = 0.1 \text{ M}$, $[\text{Cl}^-] = 0.1 \text{ M}$.

Inventory of 0.1 M NaOH: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{OH}^-] = 0.1 \text{ M}$.

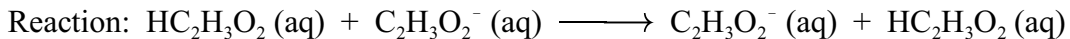


f. Inventory of 0.1 M NaHCO₃: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{HCO}_3^-] = 0.1 \text{ M}$.

Inventory of 0.1 M KOH: $[\text{K}^+] = 0.1 \text{ M}$, $[\text{OH}^-] = 0.1 \text{ M}$.

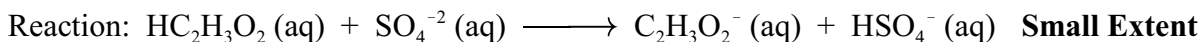


- g. Inventory of 0.1 M $\text{HC}_2\text{H}_3\text{O}_2$: $[\text{HC}_2\text{H}_3\text{O}_2] = 0.1 \text{ M}$.
 Inventory of 0.1 M $\text{NaC}_2\text{H}_3\text{O}_2$: $[\text{Na}^+] = 0.1 \text{ M}$, $[\text{C}_2\text{H}_3\text{O}_2^-] = 0.1 \text{ M}$.

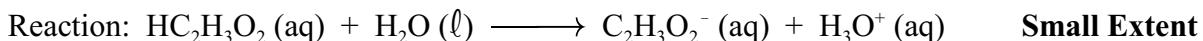


NOTE: This reaction is between the strongest acid and the strongest base present in appreciable amount but as the reactants and products are the same, the reaction goes nowhere!

- h. Inventory of 0.1 M $\text{HC}_2\text{H}_3\text{O}_2$: $[\text{HC}_2\text{H}_3\text{O}_2] = 0.1 \text{ M}$.
 Inventory of 0.1 M MgSO_4 : $[\text{Mg}(\text{H}_2\text{O})_6^{+2}] = 0.1 \text{ M}$, $[\text{SO}_4^{-2}] = 0.1 \text{ M}$.



- i. Inventory of 0.1 M $\text{HC}_2\text{H}_3\text{O}_2$: $[\text{HC}_2\text{H}_3\text{O}_2] = 0.1 \text{ M}$.



- j. Inventory of pure HNO_3 is HNO_3 .
 Inventory of pure NaOH is NaOH .



QUESTIONS ON OXIDATION AND REDUCTION

47. **Oxidation** is the process in which electrons are formally lost.
Reduction is the process in which electrons are formally gained.
48. 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.
49. 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.
50. 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.
51. 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

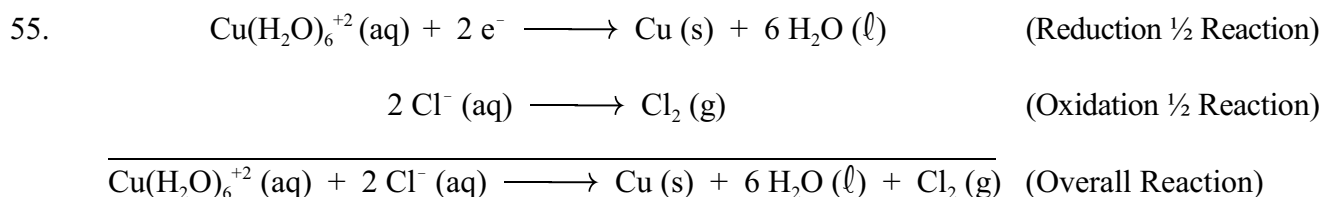
- b. Xe (group 8) Max Ox State = Group# = +8
Min Ox State = (Group # - 8) = (8 - 8) = 0
- c. Cl (group 7) Max Ox State = Group# = +7
Min Ox State = (Group # - 8) = (7 - 8) = -1
- d. Na (group 1) Max Ox State = Group# = +1
Min Ox State = (Group # - 8) = (1 - 8) = -7 Never achieved!
- e. Se (group 6) Max 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

52. (+) (+7) (-2) (+6) (-2) (+6) (-1)
a. Cs Cl O₄ b. S O₃ c. U F₆
- (+4) (-1) (+) (+5) (-2) (+3) (+6) (-2)
d. Xe F₄ e. K N O₃ f. Al₂ (S O₄)₃
- (+1) (-1) (+1) (+6) (-2) (+8) (-2)
g. Cs H h. Na₂ Cr₂ O₇ i. Os O₄
- (-3) (+1) (+4) (-2) (+2) (-2) (0)
j. (N H₄)₂ C O₃ k. Ba Se l. S₈
- (+2) (+6) (-2) (+5) (-2) (+2) (-1)!!!
m. Mg₃ U O₆ n. N O₂⁺ o. Sr O₂
- (+8) (-2) (+6) (-2) (-3) (+1)
p. Xe O₆⁻⁴ q. S₂ O₇⁻² r. As H₃

53. a. The Ox. St. of Mn increases from +4 in MnO₂ to +7 in MnO₄⁻ 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 BiO₃⁻ 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 SO₂ to +6 in SO₃ 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 ClO₃⁻ 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 N₂O₄ to +1 in N₂O 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 H₂O₂ to -2 in H₂O and thus the O gained 1 electron each during the reaction. Therefore, O underwent a reduction.

54. 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.

- 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).
- 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.
- 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.
- 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 $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ to +6 in CrO_4^{-2} . This is the loss of electrons and therefore $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ is the reducing agent.
- 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.



56. A. Reaction (i): $2 \text{K} + 2 \text{H}_2\text{O} \longrightarrow 2 \text{K}^+ + \text{H}_2 + 2 \text{OH}^-$ **Very Large Extent**
 Reaction (ii): $\text{Ca} + 2 \text{H}_2\text{O} \longrightarrow \text{Ca}^{+2} + \text{H}_2 + 2 \text{OH}^-$ **Large Extent**
 Reaction (iii): $\text{Cu} + 2 \text{H}_2\text{O} \longrightarrow \text{Cu}^{+2} + \text{H}_2 + 2 \text{OH}^-$ **Small Extent**
 Reaction (iv): $\text{Cu} + 2 \text{Ag}^+ \longrightarrow \text{Cu}^{+2} + 2 \text{Ag}$ **Large Extent**
- B. Reaction (i): $\text{K} > \text{H}_2$
 Reaction (ii): $\text{Ca} > \text{H}_2$ and $\text{K} > \text{Ca}$
 Reaction (iii): $\text{H}_2 > \text{Cu}$
 Reaction (iv): $\text{Cu} > \text{Ag}$

C. Reaction (i): $\text{H}_2\text{O} > \text{K}^+$

Reaction (ii): $\text{H}_2\text{O} > \text{Ca}^{+2}$ and $\text{Ca}^{+2} > \text{K}^+$

Reaction (iii): $\text{Cu}^{+2} > \text{H}_2\text{O}$

Reaction (iv): $\text{Ag}^+ > \text{Cu}^{+2}$

D.

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

57. a. $2 \text{Na} + \text{I}_2 \longrightarrow 2 \text{Na}^+ + 2 \text{I}^-$ (or 2NaI if no solvent is present)
- b. $16 \text{Cs} + \text{S}_8 \longrightarrow 16 \text{Cs}^+ + 8 \text{S}^{-2}$ (or $8 \text{Cs}_2\text{S}$ if no solvent is present)
- c. $6 \text{Mg} + \text{P}_4 \longrightarrow 6 \text{Mg}^{+2} + 4 \text{P}^{-3}$ (or $2 \text{Mg}_3\text{P}_2$ if no solvent is present)
- d. $4 \text{Al} + 3 \text{O}_2 \longrightarrow 4 \text{Al}^{+3} + 6 \text{O}^{-2}$ (or $2 \text{Al}_2\text{O}_3$ if no solvent is present)
- e. $2 \text{Be} + \text{O}_2 \longrightarrow 2 \text{Be}^{+2} + 2 \text{O}^{-2}$ (or 2BeO if no solvent is present)
- f. $4 \text{Li} + \text{O}_2 \longrightarrow 4 \text{Li}^+ + 2 \text{O}^{-2}$ (or $2 \text{Li}_2\text{O}$ if no solvent is present)
- g. $\overset{(0)}{\text{C}} + \overset{(0)}{\text{O}_2} \longrightarrow \overset{(+4)}{\text{C}}\overset{(-2)}{\text{O}_2}$
- h. $\text{Zn} + \text{Br}_2 \longrightarrow \text{Zn}^{+2} + 2 \text{Br}^-$ (or ZnBr_2 if no solvent is present)
- i. $4 \text{Sc} + 3 \text{O}_2 \longrightarrow 4 \text{Sc}^{+3} + 6 \text{O}^{-2}$ (or $2 \text{Sc}_2\text{O}_3$ if no solvent is present)
- j. $2 \text{K} + \text{H}_2 \longrightarrow 2 \text{K}^+ + 2 \text{H}^-$ (or 2KH if no solvent is present)
- k. $\text{Ba} + \text{H}_2 \longrightarrow \text{Ba}^{+2} + 2 \text{H}^-$ (or BaH_2 if no solvent is present)
- l. $\overset{(0)}{\text{P}_4} + 10 \overset{(0)}{\text{F}_2} \longrightarrow 4 \overset{(+5)}{\text{P}}\overset{(-1)}{\text{F}_5}$
- m. $\overset{(0)}{\text{H}_2} + \overset{(0)}{\text{Br}_2} \longrightarrow 2 \overset{(+1)}{\text{H}}\overset{(-1)}{\text{Br}}$
- n. $8 \overset{(0)}{\text{H}_2} + \overset{(0)}{\text{S}_8} \longrightarrow 8 \overset{(+1)}{\text{H}}\overset{(-1)}{\text{S}}$
- o. $2 \overset{(0)}{\text{H}_2} + \overset{(0)}{\text{O}_2} \longrightarrow 2 \overset{(+1)}{\text{H}}\overset{(-1)}{\text{O}}$