CHEMISTRY 103 – Help Sheet #3
Chapter 3 (Part I); Sections 3.1-3.5
Do the topics appropriate for your lecture
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http://www.chem.wisc.edu/areas/clc (Resource page)

Nuggets: Balancing Rxns; Electrolytes; Acids/Bases; Solubility Rules; Writing Molecular, Complete Ionic, and Net Ionic Rxns; Types of Reactions; Redox rxns: assigning oxidation numbers; ID, redox rxn, what’s oxidized, reduced, oxidizing agent, reducing agent

CHEMICAL EQUATIONS: reactants (the starting reagents) yield products (the ending materials)
Be able to balance chemical equations; balanced reaction means the number of atoms and total charges on each side of the reaction are the same

ELECTROLYTES: A chemical that produces ions; more ions → more electrical current/better conductor
Strong-Electrolyte: Produces large numbers of ions: soluble ionic compounds; strong acids; strong bases
Weak-Electrolyte: Produces only a small quantity of ions: weak acids; weak bases
Nonelectrolyte: Produces no ions: insoluble ionic compounds; molecular compounds; e.g., sugar

(Ionic Compounds: Metal + nonmetal (or polyatomic ion); Molecular Compounds: 2 nonmetals)

Acids: Produce H⁺ in solution (e.g., HCl → H⁺ + Cl⁻); begin with H in the formula (except: H₂O, H₂O₂)

Strong acids (Table 3.2): acids that completely break up (dissociate) into H⁺ and A⁻; strong electrolytes
HCl (hydrochloric acid), HBr (hydrobromic acid), HI (hydroiodic acid), HNO₃ (nitric acid), H₂SO₄ (sulfuric acid), HClO₄ (perchloric acid) – best to memorize all formulas/names

Weak acids: an acid that is not a strong acid; dissociate (break up) a little; weak electrolytes
Common weak acids (there are many weak acids): CH₃COOH = CH₃CO₂H = HAc = acetic acid; H₃PO₃ (phosphoric acid); H₂CO₃ (carbonic acid); HCN (hydrocyanic); HCOOH (formic acid); C₆H₅COOH (benzoic acid) – best to memorize acetic acid formula/name

Bases: Produce OH⁻ in solution (e.g., NaOH → Na⁺ + OH⁻)

Strong bases (Table 3.2): bases that completely dissolve into OH⁻; strong electrolytes
Group IA hydroxides: LiOH, NaOH, KOH; Group IIA hydroxides: Ca(OH)₂, Sr(OH)₂ and Ba(OH)₂ – best to memorize all formulas/names

Weak bases: a base that is not a strong base; produce a little OH⁻; weak electrolytes;
Common weak base (there are many weak bases): NH₃ (ammonia) easier when writing reactions to use:
NH₄OH = NH₃ + H₂O; CH₃NH₂ (methylamine) – best to memorize ammonia formula/name

SOLUBILITY RULES (see Table 3.1)
Soluble: Li⁺, Na⁺, K⁺, Rb⁺, Cs⁺; NH₄⁺; NO₃⁻; ClO₃⁻; ClO₄⁻; CH₃COO⁻ = C₂H₅O₂⁻;
Cl⁻, Br⁻, I⁻ (not: Ag⁺, Hg₂²⁺, Pb⁺²⁺); SO₄⁻² (not: Ca²⁺, Sr⁺², Ba⁺², Pb⁺²⁺);

Insoluble: OH⁻; S⁻²; CO₃⁻²; PO₄⁻³; (exceptions for all: Li⁺, Na⁺, K⁺, Rb⁺, Cs⁺, NH₄⁺, additionally for OH⁻: Ba(OH)₂)

CONDUCTIVITY – how well a solution can pass an electrical current; more ions → greater conductivity; (more ions: the more soluble an ionic compound is the more ions dissolve; molecular compound → no ions!)
HOW TO WRITE REACTIONS

1. Overall or Molecular Reaction: All compounds are written in a molecular form; no ions.
   1. If needed, given names → Translate names into reactant formulas.
   2. Write products by switching reactant parts in ionic or acid/base reactions. For combustion reactions products are CO₂ and H₂O. When writing products, use only one reactant part (anion/cation) even if there is more than one reactant part on the reactant side (i.e., all product parts should initially have a subscript of 1);
   3. Assign charges to product parts.
   4. Balance product formulas by adding subscripts as needed.
   5. Balance the overall reaction.

Example 1: Calcium nitrate and sodium phosphate are mixed; write the molecular reaction.
   1. Ca(NO₃)₂ + Na₃PO₄ → (translated names into formulas; calcium nitrate = Ca(NO₃)₂; sodium phosphate = Na₃PO₄)
   2. Ca(NO₃)₂ + Na₃PO₄ → CaPO₄ + NaNO₃ (switch partners; use only 1 reactant part on product side; note 3 Na on left side but only 1 Na on the right side)
   3. Ca(NO₃)₂ + Na₃PO₄ → Ca²⁺PO₄³⁻ + Na⁺NO₃⁻ (assign charges to product parts)
   4. Ca(NO₃)₂ + Na₃PO₄ → Ca₃(PO₄)₂ + Na₁(NO₃)₁ (balance product formulas with subscripts using charges)
   5. 3Ca(NO₃)₂ + 2Na₃PO₄ → Ca₃(PO₄)₂ + 6NaNO₃ (balance reaction with coefficients); molecular rxn

2. Complete Ionic Reaction: Break the appropriate compounds into aqueous ions

   Break up into ions if chemical is Soluble Ionic (metal+nonmetal & solubility rules) or Strong Acid (memorized) or Strong Base (memorized)

   Exception: H₂CO₃(aq) → H₂O(l) + CO₂(g) (used with gas-forming reactions)

   Ca(NO₃)₂ – soluble ionic → break-up; Na₃PO₄ – soluble ionic → break-up; Ca₃(PO₄)₂ – insoluble ionic →
   don’t break-up; NaNO₃ – soluble ionic → break-up

   Note 1: the “3” in front of Ca(NO₃)₂ acts on both the Ca⁺² and the NO₃⁻;

   Note 2: Not written as 3(NO₃)₂⁻; (NO₃)₂⁻ implies the 2NO₃⁻ are bonded together; 6NO₃⁻ implies 6 separate NO₃⁻;

   Note 3: polyatomic ions are treated as a group and are not broken apart; it is 6NO₃⁻ and not 6N + 18O

   Complete ionic rxn: 3Ca⁺²(aq) + 6NO₃⁻(aq) + 6Na⁺(aq) + 2PO₄⁻³(aq) → Ca₃(PO₄)₂(s) + 6Na⁺(aq) + 6NO₃⁻(aq)

3. Net Ionic Reaction: Ions that "react" are included; other ions (Spectator Ions) are not included

   Cancel out spectator ions from Complete Ionic Reaction.

   Watch out for H₂CO₃; if everything cancels out → No reaction!

   Net ionic rxn: 3Ca⁺²(aq) + 2PO₄⁻³(aq) → Ca₃(PO₄)₂(s) [Na⁺(aq), NO₃⁻(aq) were canceled]

Example 2: Write the molecular, complete ionic, and net ionic rxns for the rxn of acetic acid with barium hydroxide.

Answer: Molecular rxn: Step 1: names → formulas: CH₃COOH (memorized) + Ba(OH)₂ → (assign charges; balance reactant formulas) → H⁺CH₃COO⁻¹ + Ba⁺²(OH⁻¹)²

Step 2: switch partners; use only 1: CH₃COOH + Ba(OH)₂ → HOH + Ba(CH₃COO)

Step 3: assign charges to products: CH₃COOH + Ba(OH)₂ → H⁺¹OH⁻¹ + Ba⁺²CH₃COO⁻¹

Step 4: balance product formulas: CH₃COOH + Ba(OH)₂ → HOH + BaCH₃COO²

Step 5: balance rxn: Molecular rxn: 2 CH₃COOH + Ba(OH)₂ → 2HOH + Ba(CH₃COO)₂

Complete ionic rxn: Step 1: break strong acids (SA), strong bases (SB), and soluble ionic compounds into ions; don’t break up weak acids (WA), weak bases (WB), insoluble ionic compounds, or molecular compounds

CH₃COOH – WA → don’t break up; Ba(OH)₂ – SB → break up; HOH – molecular compound → don’t break up; Ba(CH₃COO)₂ – ionic (has a metal) and is soluble (has CH₃COO⁻ and is not a WA) → break up: Complete ionic rxn: 2CH₃COOH + Ba⁺² + 2OH⁻ → 2H₂O + Ba⁺² + 2CH₃COO⁻

Net ionic rxn: Step 1: cancel out ions on both sides of the reaction: 2CH₃COOH + 2OH⁻ → 2H₂O + 2CH₃COO⁻

Simplify reaction coefficients if possible: Net ionic rxn: CH₃COOH + OH⁻ → H₂O + CH₃COO⁻

Add phases (s, l, g, aq) to all 3 reactions:

Molecular rxn: 2CH₃COOH (aq) + Ba(OH)₂(aq) → 2HOH(l) + Ba(CH₃COO)₂(aq)

Complete ionic rxn: 2CH₃COOH (aq) + Ba⁺²(aq) + 2OH⁻(aq) → 2H₂O(l) + Ba⁺²(aq) + 2 CH₃COO⁻(aq)

Net ionic rxn: CH₃COOH (aq) + OH⁻(aq) → H₂O(l) + CH₃COO⁻(aq)
TYPES OF REACTIONS and Writing Molecular, Complete Ionic, and Net Ionic Reactions

1. **Precipitation:** 2 aqueous/soluble ionic compounds "switch" partners and produce a solid
   - \( \text{Ba(NO}_3\text{)}_2(\text{aq}) + K_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{KNO}_3(\text{aq}) \) (molecular reaction)
   - \( \text{Ba}^{2+}(\text{aq}) + 2\text{NO}_3(\text{aq}) + 2\text{K}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{K}^+(\text{aq}) + 2\text{NO}_3(\text{aq}) \) (complete ionic rxn)
   - \( \text{Ba}^{2+}(\text{aq}) + \text{K}_2\text{SO}_4(\text{aq}) \) and \( \text{KNO}_3 \rightarrow \) soluble ionic \( \rightarrow \) break up; \( \text{BaSO}_4 \rightarrow \) insoluble ionic \( \rightarrow \) don’t break up
   - \( \text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) \) (net ionic reaction)

2. **Acid/Base (neutralization):** Acid + Base \( \rightarrow \) H\(_2\)O + salt  (salt = ionic compound that is usually soluble)
   - \( 2\text{HNO}_3(\text{aq}) + \text{Ba(OH)}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O(l)} + \text{Ba(NO}_3\text{)}_2(\text{aq}) \) (molecular reaction)
   - \( 2\text{H}^+(\text{aq}) + 2\text{NO}_3(\text{aq}) + \text{Ba}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O(l)} + \text{Ba}^{2+}(\text{aq}) + 2\text{NO}_3(\text{aq}) \) (complete ionic rxn)
     - \( \text{HNO}_3 \rightarrow \) strong acid \( \rightarrow \) break up; \( \text{Ba(OH)}_2 \rightarrow \) strong base \( \rightarrow \) break up; \( \text{Ba(NO}_3\text{)}_2 \rightarrow \) soluble ionic \( \rightarrow \) break up;
     - \( \text{H}_2\text{O} \rightarrow \) molecular \( \rightarrow \) don’t break up
   - \( \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O(l)} \) (net ionic rxn)

3. **Gas-Forming:** produces a gas  (common gas-forming reaction: yield CO\(_2\); less common: yield SO\(_2\) and H\(_2\)S)
   - acid + (\( \text{HCO}_3^-(\text{aq}) \) or \( \text{CO}_3^{2-}(\text{aq}) \)) \( \rightarrow \) \( \text{H}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}_2\text{O(l)} + \text{CO}_2(\text{g}) \)
     - \( 2\text{HCl(\text{aq})} + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \) \( \text{H}_2\text{CO}_3(\text{aq}) + 2\text{NaCl(\text{aq})} \) (molecular reaction not yet finished)
     - the \( \text{H}_2\text{CO}_3(\text{aq}) \) breaks up: \( \text{H}_2\text{CO}_3(\text{aq}) \rightarrow \text{H}_2\text{O(l)} + \text{CO}_2(\text{g}) \) to yield an overall reaction:
     - \( 2\text{HCl(\text{aq})} + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \) \( \text{H}_2\text{O(l)} + \text{CO}_2(\text{g}) + 2\text{NaCl(\text{aq})} \) (molecular reaction finished)
     - \( 2\text{H}^+(\text{aq}) + 2\text{Cl}^-(\text{aq}) + 2\text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{H}_2\text{O(l)} + \text{CO}_2(\text{g}) + 2\text{Na}^+(\text{aq}) + 2\text{Cl}^-(\text{aq}) \) (complete ionic rxn)
     - \( \text{HCl} \rightarrow \) strong acid \( \rightarrow \) break up; \( \text{Na}_2\text{CO}_3, \text{NaCl} \rightarrow \) soluble ionic \( \rightarrow \) break up; \( \text{H}_2\text{O, CO}_2 \rightarrow \) molecular \( \rightarrow \) don’t break up
     - \( 2\text{H}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{H}_2\text{O(l)} + \text{CO}_2(\text{g}) \) (net ionic reaction)
     - Other gas forming reactions: acid + \( \text{SO}_3^{2-}(\text{aq}) \) \( \rightarrow \) \( \text{H}_2\text{O(l)} + \text{SO}_2(\text{g}) \)
     - Other gas forming reactions: acid + \( \text{S}^{2-}(\text{aq}) \) \( \rightarrow \) \( \text{H}_2\text{S(g)} \)

4. **Redox: oxidation numbers change** for elements as they go from reactants to products (see below)
   - **Displacement:** metal + (acid or metal salt) \( \rightarrow \) metal/element + metal salt
     - \( \text{A} + \text{BX} \rightarrow \text{AX} + \text{B} \)
     - \( \text{Mg}(\text{s}) + 2\text{HCl(\text{aq})} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g}) \) (molecular reaction)
     - \( \text{Mg}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2(\text{g}) \) (net ionic reaction)

**Combustion: a type of redox rxn:** Hydrocarbon (hydrogen + carbon) reacting with \( \text{O}_2 \) to form \( \text{H}_2\text{O} \) and \( \text{CO}_2 \)
   - \( \text{C}_x\text{H}_y + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O(}\text{g}) \) (unbalanced)
     - \( 2\text{C}_8\text{H}_{18}(\text{g}) + 25\text{O}_2(\text{g}) \rightarrow 16\text{CO}_2(\text{g}) + 18\text{H}_2\text{O(}\text{g}) \) (molecular reaction)
     - \( 2\text{C}_8\text{H}_{18}(\text{g}) + 25\text{O}_2(\text{g}) \rightarrow 16\text{CO}_2(\text{g}) + 18\text{H}_2\text{O(}\text{g}) \) (complete ionic reaction)
     - \( (\text{C}_8\text{H}_{18}, \text{O}_2, \text{H}_2\text{O, CO}_2 \rightarrow \) molecular \( \rightarrow \) don’t break up)
     - \( 2\text{C}_8\text{H}_{18}(\text{g}) + 25\text{O}_2(\text{g}) \rightarrow 16\text{CO}_2(\text{g}) + 18\text{H}_2\text{O(}\text{g}) \) (net ionic reaction)
REDOX - oxidation - lose e⁻; reduction - gain e⁻; **redox rxn occurs when there is a change in oxidation number**

Oxidation reaction **cannot** occur without reduction reactions, and vice-versa

LEO the lion goes GER (LEO - Lose Electrons is Oxidation; GER - Gain Electrons is Reduction)

Reducing agent - that which causes something else to be reduced; the **reducing agent is oxidized**

Oxidizing agent - that which causes something else to be oxidized; the **oxidizing agent is reduced**

1. **ASSIGNING OXIDATION NUMBERS** - Bookkeeping of electrons

   1. Elements in elemental form 0
   2. In a compound:
      a. Group 1A (Li, Na, ...) +1 (always)
      b. Group 2A (Be, Mg, ...) +2 (always)
      c. F -1 (always)
      d. H +1 (usually; can be -1 in MH_x compds; e.g., NaH)
      e. O -2 (usually; -1 in O_2⁻ compds (e.g., H_2O_2); -1/2 in O_2⁻ compds (e.g., KO_2))

3. Sum Rule: **Sum of all the oxidation numbers = total charge on compound**

   **Example 1:**
   Assign ox num to all atoms in PO_4^{3-}: 1(P) + 4(O) = -3; Assign O = -2 → 1(P) + 4(-2) = -3; 1(P) + (-8) = -3; P = +5

   **Example 2:** Assign ox num to all atoms in CuSO_4: Two unknowns: Cu and S; break into 2 parts and look for a polyatomic ion: Cu and SO_4; assign charge (not ox num) to SO_4 → SO_4^{2-} (memorized); therefore, Cu → Cu^{+2} since entire compound, CuSO_4, is neutral (+2 + -2 = 0); Cu^{+2} has ox num = +2; SO_4^{2-}: 1(S) + 4(O) = -2; Assign O = -2 → 1(S) + 4(-2) = -2;
   1(S) + (-8) = -2; S = +6

2. **OXIDIZED, REDUCED, OXIDIZING AGENT, REDUCING AGENT**

   If ox num get more positive ⇒ oxidized; If ox num get more negative ⇒ reduction

   ![oxidation and reduction](image)

   Chemical oxidized = reducing agent; Chemical reduced = oxidizing agent;
   Chemical oxidized, Chemical reduced, Oxidizing agent, Reducing agent = reactants only; no products

3. **IS IT A REDOX RXN**

   **Redox reaction occurs when oxidation numbers change in a reaction** (combustion rxns are redox rxns)

   If reaction is an acid/base, precipitation, or gas-forming – it’s **not a redox reaction**!

   If a reactant acts as both the oxidizing and reducing agent → reaction is called a **disproportionation reaction**

   **Example:** 2CO(g) → C(s) + CO_2(g);
   reactant: ox num C in CO = +2; products: ox num C in C(s) = 0 (C was reduced); ox num C in CO_2(g) = +4 (C was oxidized)
4. METAL ACTIVITY SERIES (if covered!) – see Table 3.4 on how easily a metal is oxidized; when the metal is above another metal cation – reaction occurs and the metal is oxidized and the metal cation forms a solid (e.g., Mn(s) and Fe$^{+2}$(aq)); when the metal is below a metal cation – no reaction occurs (e.g., Cu(s) and Cr$^{+3}$(aq))

<table>
<thead>
<tr>
<th>Reaction Occurs</th>
<th>No Reaction</th>
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<tbody>
<tr>
<td>when metal is above the cation</td>
<td>when metal is below the cation</td>
</tr>
<tr>
<td>Mn(s) → Mn$^{+2}$(aq) + 2e$^{-}$</td>
<td>Mn(s) → Mn$^{+2}$(aq) + 2e$^{-}$</td>
</tr>
<tr>
<td>Cr(s) → Cr$^{+3}$(aq) + 3e$^{-}$</td>
<td>Cr(s) → Cr$^{+3}$(aq) + 3e$^{-}$</td>
</tr>
<tr>
<td>Fe(s) → Fe$^{+2}$(aq) + 2e$^{-}$</td>
<td>Fe(s) → Fe$^{+2}$(aq) + 2e$^{-}$</td>
</tr>
<tr>
<td>H$_2$(g) → 2H$^+$(aq) + 2e$^{-}$</td>
<td>H$_2$(g) → 2H$^+$(aq) + 2e$^{-}$</td>
</tr>
<tr>
<td>Cu(s) → Cu$^{+2}$(aq) + 2e$^{-}$</td>
<td>Cu(s) → Cu$^{+2}$(aq) + 2e$^{-}$</td>
</tr>
</tbody>
</table>

Example: Mn(s) + FeBr$_2$(aq) → MnBr$_2$(aq) + Fe(s)  
These 2 reactions happened: Mn(s) → Mn$^{+2}$(aq) and Fe$^{+2}$(aq) → Fe(s)

Example: 2Cr(s) + 6HCl(aq) → 2CrCl$_3$(aq) + 3H$_2$(g)  
These 2 reactions happened: Cr(s) → Cr$^{+3}$(aq) and 2H$^+$(aq) → H$_2$(g)

Example: Cu(s) + Cr$^{+3}$(aq) → no reaction  → Cu is below Cr$^{+3}$

What drives a chemical reaction to proceed? (if covered)

Enthalpy: the energy change (often approximated as heat) that occurs in a reaction; in general, a reaction is favored when the system goes to a lower energy (e.g., heat is given off)

Entropy: measure of the randomness or disorder of a system or the dispersal of energy in a system; in general, a reaction is favored when the system becomes more random/disordered or the energy of the system is more dispersed

Equilibrium: a measure of the quantities of products and reactants of a given reaction under specified conditions; if the products are the major or favored chemical at the end of the reaction, this indicates the reaction tends to proceed forward and form products

Electrostatic interactions: the cations and anions in the product chemicals being attracted to one another because of the positive and negative charges

Bond formation: covalent (sharing of electrons) bond formation; the energy of the bonds formed in the products being overall lower in energy (stronger bonds) than the reactants

1. Balance the following equations.
   a. Mg(s) + SiO$_2$(s) → MgO(s) + Si(s)  
b. Ca(s) + N$_2$(g) → Ca$_3$N$_2$(s)
   c. CH$_3$OH(l) + O$_2$(g) → CO$_2$(g) + H$_2$O(l)  
d. CaCl$_2$(s) + Na$_2$CO$_3$(s) → CaCO$_3$(s) + NaCl(s)
   e. P$_4$O$_{10}$(s) + H$_2$O(l) → H$_3$PO$_4$(aq)  
f. C$_6$H$_6$(l) + O$_2$(g) → CO$_2$(g) + H$_2$O(l)

2. Write and balance a reaction from the description given (recall combustion refers to the reaction of a hydrocarbon with O$_2$(g) to produce water, H$_2$O(l), and carbon dioxide, CO$_2$). Include phases [(aq), (s), (l), (g)].
   a. pentane (C$_5$H$_{12}$(l)) is combusted  
b. ethylene (C$_2$H$_4$(g)) is combusted
   c. sodium metal reacts with oxygen gas  
d. calcium metal reacts with solid phosphorus

3. Write the balanced molecular reactions from each description. Include phases [(aq), (s), (l), (g)].
   a. Solid dinitrogen pentoxide reacts with water to form aqueous nitric acid.
   b. Solid ammonium nitrate decomposes to form gaseous dinitrogen monoxide and water.
   c. Solid manganese(II) carbonate breaks down to form solid manganese(II) oxide and carbon dioxide.
4. Write balanced *molecular reactions* for each of the following. Include phases [(aq), (s), (l), (g)].
   a. HCl(aq) and Ba(OH)\(_2\)(aq) reacting
   b. AgNO\(_3\)(aq) and NaBr(aq) reacting
   c. H\(_2\)O(l) is decomposed into its elements

5. a. What are the six common strong acids and six common strong bases (give name/chemical formula)?
   b. Identify (name and chemical formula) one common weak acid and one common weak base.

6. Use the reactions below to answer the following 3 questions.
   a. HCl(aq) + KOH(aq) →
   b. HC\(_2\)H\(_3\)O\(_2\)(aq) + NaHCO\(_3\)(aq) →
   c. NH\(_3\)(aq) + H\(_2\)SO\(_4\)(aq) →
   d. Pb(NO\(_3\))\(_2\)(aq) + Na\(_2\)S(aq) →
   e. None of the above.
   I. Which of the following will lead to a precipitation reaction?
   II. Which of the following is an example of a weak base reacting with a strong acid?
   III. Which of the following is an example of a gas-forming reaction?

7. Identify each type of reaction as either acid-base, gas-forming, or precipitation reaction.
   a. 2KI(aq) + Pb(NO\(_3\))\(_2\)(aq) → 2KNO\(_3\)(aq) + PbI\(_2\)(s)
   b. HCl(aq) + NaOH(aq) → H\(_2\)O(l) + NaCl(aq)
   c. Cd(NO\(_3\))\(_2\)(aq) + H\(_2\)S(g) → CdS(s) + HNO\(_3\)(aq)
   d. HF(aq) + NaOH(aq) → NaF(aq) + H\(_2\)O(l)
   e. K\(_2\)CO\(_3\)(aq) + 2HC\(_2\)H\(_3\)O\(_2\)(aq) → 2KC\(_2\)H\(_3\)O\(_2\)(aq) + H\(_2\)O(l) + CO\(_2\)(g)

8. Which reaction is a weak acid reacting with a weak base reaction?
   a. HCl(aq) + NaOH(aq) → H\(_2\)O(l) + NaCl(aq)
   b. AgNO\(_3\)(aq) + NaCl(aq) → AgCl(s) + NaNO\(_3\)(aq)
   c. HC\(_2\)H\(_3\)O\(_2\)(aq) + LiOH(aq) → NaC\(_2\)H\(_3\)O\(_2\)(aq) + H\(_2\)O(l)
   d. HF(aq) + NH\(_3\)(aq) → NH\(_4\)⁺(aq) + F⁻(aq)

9. Write the balanced combustion reactions for:   a. pentane, C\(_5\)H\(_{12}\)   b. methane, CH\(_4\)

10. Write the balanced *net ionic reaction* for each of the following. If no reaction occurs, write no reaction. (Hint: Start by writing a molecular reaction, then a complete ionic, and then a net ionic – it’s long to do it this way but it also is instructive.) Include phases [(aq), (s), (l), (g)].
   a. An aqueous solution of potassium chloride, KCl(aq), is combined with an aqueous solution of silver(I) nitrate, AgNO\(_3\)(aq), to yield an insoluble precipitate.
   b. Aqueous Pb(NO\(_3\))\(_2\)(aq) and aqueous NaI(aq) are combined to yield an insoluble precipitate.
   c. A solution of hydrochloric acid, HCl(aq), and a solution of potassium hydroxide, KOH(aq) are combined.
   d. A balloon containing oxygen gas and hydrogen gas is combusted.
   e. Aqueous barium chloride and aqueous potassium sulfate are mixed together to yield an insoluble precipitate.

11. Identify the following chemicals when they are dissolved into water as a strong, weak, or nonelectrolytes.
   a. NaCl       b. HCl       c. HC\(_2\)H\(_3\)O\(_2\)       d. sugar       e. BaSO\(_4\)
   f. NH\(_3\)       g. H\(_2\)SO\(_4\)       h. NaOH       i. HF
12. Which of the following compounds will form a solution that is a poor conductor of electricity?
a. NaCl b. KOH c. NH₄C₂H₅O₂ d. HClO₄ e. none of the above

13. Assign the oxidation numbers for each element present.
a. Na b. Fe c. Cl₂ d. Li⁺ e. Br⁻ f. NO     g. NO₂    h. NaCl i. NaNO₃ j. NO₃⁻ k. PO₄³⁻ l. H₂O
m. H₂SO₄ n. Ca(NO₃)₂ o. S₂O₃²⁻ p. CO₃²⁻ q. MnSO₄ r. Cr₃(PO₄)₂ s. CuNO₃ t. NH₄NO₃

14. Identify what is being oxidized, reduced, what the oxidizing agent is, and what the reducing agent is. (The reactions don't need to be balanced, and don't try to balance them.)
a. S²⁻ + NO₃⁻ → NO₂ + S₈           b. NO₃⁻ + Cu → NO + Cu²⁺
c. MnO₄⁻ + SO₂ → SO₄²⁻ + Mn²⁺       d. Hg₂²⁺ + H₂S → Hg + S₈

15. A white compound is found and is either Pb(NO₃)₂ or Ba(NO₃)₂. Which one of the following compounds could be used with water and the unknown white compound to determine the identity of the unknown compound?
a. HNO₃ b. HCl c. AgNO₃ d. KClO₄ e. C₂H₅OH (ethanol)

16. A white compound is found and is either K₂CO₃ or AgNO₃. Which one of the following compounds could be used with water and the unknown white compound to determine the identity of the unknown compound?
a. BaCl₂ b. NaClO₄ c. Li₂SO₄ d. CaI₂ e. HNO₂

17. (if covered!) Using the activity series shown on the prior page above (Table 3.4), complete the reactions below by writing the molecular and net ionic reactions. (Not all instructors cover this topic!)
a. Ni(s) + HBr(aq) → b. Al(s) + AgNO₃(aq) →
c. Fe(s) + Zn(NO₃)₂(aq) → d. Mg(s) + SnSO₄(aq) →

ANSWERS
1. a. 2Mg(s) + SiO₂(s) → 2MgO(s) + Si(s) b. 3Ca(s) + N₂(g) → Ca₃N₂(s)
   c. 2CH₃OH(l) + 3O₂(g) → 2CO₂(g) + 4H₂O(l) d. CaCl₂(s) + Na₂CO₃(s) → CaCO₃(s) + 2NaCl(s)
   e. P₂O₁₀(s) + 6H₂O(l) → 4H₃PO₄(aq) f. 2C₆H₆(l) + 15O₂(g) → 12CO₂(g) + 6H₂O(l)
2. a. C₅H₁₂(l) + 8O₂(g) → 5CO₂(g) + 6H₂O(g) b. C₂H₄(g) + 3O₂(g) → 2CO₂(g) + 2H₂O(g)
   c. 4Na(s) + O₂(g) → 2Na₂O(s) d. 3Ca(s) + 2P(s) → Ca₃P₂(s)
3. a. N₂O₅(s) + H₂O(l) → 2HNO₃(aq) b. NH₄NO₃(s) → N₂O(g) + 2H₂O(l) c. MnCO₃(s) → MnO(s) + CO₂(g)
4. a. 2HCl(aq) + Ba(OH)₂(aq) → 2H₂O(l) + BaCl₂(aq) b. AgNO₃(aq) + NaBr(aq) → AgBr(s) + NaNO₃(aq)
   c. 2H₂O(l) → O₂(g) + 2H₂(g)
5. a. Acids: HCl/hydrochloric acid, HBr/hydrobromic acid, HI/hydroiodic acid, H₂SO₄/sulfuric acid, HNO₃/nitric acid, HClO₄/perchloric acid; Bases: LiOH/lithium hydroxide, NaOH/sodium hydroxide, KOH/potassium hydroxide, Ca(OH)₂/calcium hydroxide, Sr(OH)₂/strontium hydroxide, Ba(OH)₂/barium hydroxide;
b. Weak acid: H₂C₂H₅O₂/acetic acid (also written CH₃COOH); Weak Base: NH₃/ammonia (also written NH₄OH)
6. I. d II. c III. b
7. a. precipitation b. acid/base c. precipitation d. acid/base e. gas-forming
8. d ("a" = strong acid + strong base; "b" = precipitation; "c" = weak acid + strong base)
9. a. C₅H₁₂ + 8O₂ → 5CO₂ + 6H₂O b. CH₄ + O₂ → CO₂ + 2H₂O
10. a. Molecular: KCl(aq) + AgNO₃(aq) → AgCl(s) + KNO₃(aq)
   Complete Ionic: K⁺(aq) + Cl⁻(aq) + Ag⁺(aq) + NO₃⁻(aq) → AgCl(s) + K⁺(aq) + NO₃⁻(aq)
   Net Ionic: Ag⁺(aq) + Cl⁻(aq) → AgCl(s)
b. Molecular: Pb(NO₃)₂(aq) + 2NaI(aq) → PbI₂(s) + 2NaNO₃(aq)
   Complete Ionic: Pb²⁺(aq) + 2NO₃⁻(aq) + 2Na⁺(aq) + 2I⁻(aq) → PbI₂(s) + 2Na⁺(aq) + 2NO₃⁻(aq)
   Net Ionic: Pb²⁺(aq) + 2I⁻(aq) → PbI₂(s)
c. Molecular: HCl(aq) + KOH(aq) → H₂O(l) + KCl(aq)
   Complete Ionic: H⁺(aq) + Cl⁻(aq) + K⁺(aq) + OH⁻(aq) → H₂O(l) + K⁺(aq) + Cl⁻(aq)
   Net Ionic: H⁺(aq) + OH⁻(aq) → H₂O(l)
d. Molecular, Complete Ionic, and Net Ionic: 2H₂(g) + O₂(g) → 2H₂O(g)
e. Molecular: BaCl₂(aq) + K₂SO₄(aq) → BaSO₄(s) + 2KCl(aq)
   Complete Ionic: Ba²⁺(aq) + 2Cl⁻(aq) + 2K⁺(aq) + SO₄²⁻(aq) → BaSO₄(s) + 2K⁺(aq) + 2Cl⁻(aq)
   Net Ionic: Ba²⁺(aq) + SO₄²⁻(aq) → BaSO₄(s)

11. a. strong (soluble/ionic)  b. strong (strong acid)  c. weak (weak acid)  d. non (molecular)
    e. non (insoluble/ionic)  f. weak (weak base)  g. strong (strong acid)  h. strong (strong base)
    i. weak (weak acid)

d. Molecular, Complete Ionic, and Net Ionic: 2H₂(g) + O₂(g) → 2H₂O(g)
e. Molecular: BaCl₂(aq) + K₂SO₄(aq) → BaSO₄(s) + 2KCl(aq)
   Complete Ionic: Ba²⁺(aq) + 2Cl⁻(aq) + 2K⁺(aq) + SO₄²⁻(aq) → BaSO₄(s) + 2K⁺(aq) + 2Cl⁻(aq)
   Net Ionic: Ba²⁺(aq) + SO₄²⁻(aq) → BaSO₄(s)

12. e

13. a. Na = 0  b. Fe = 0  c. Cl = 0  d. Li = +1  e. Br = -1  f. N = +2, O = -2  g. N = +4, O = -2
    h. Na = +1, Cl = -1  i. Na = +1, N = +5, O = -2  j. N = +5, O = -2  k. P = +5, O = -2  l. H = +1, O = -2
    m. H = +1, S = +6, O = -2  n. Ca = +2, N = +5, O = -2  o. S = +2, O = -2  p. C = +4, O = -2
    q. Mn = +2, S = +6, O = -2  r. Cr = +2, P = +5, O = -2  s. Cu = +1, N = 5, O = -2
    t. N = -3 (of NH₄⁺), H = +1, N = +5 (of NO₃⁻), O = -2

14. a. S²⁻ is oxidized, NO₃⁻ is reduced, NO₃⁻ is the oxidizing agent, S²⁻ is the reducing agent
    b. Cu is oxidized, NO₃⁻ is reduced, NO₃⁻ is the oxidizing agent, Cu is the reducing agent
    c. SO₂ is oxidized, MnO₄⁻ is reduced, MnO₄⁻ is the oxidizing agent, SO₂ is the reducing agent
    d. H₂S is oxidized, Hg₂²⁺ is reduced, Hg₂²⁺ is the oxidizing agent, H₂S is the reducing agent

15. b. {HCl: Pb⁺² + 2Cl⁻ → PbCl₂(s) forms a precipitate; HCl: Ba⁺² + 2Cl⁻ → BaCl₂(aq) is soluble; hence, if HCl is added and a
    precipitate forms, then the unknown was Pb(NO₃)₂ while if HCl is added and no precipitate forms, the unknown was Ba(NO₃)₂; all
    the other choices will yield no reaction and hence would not distinguish between these two chemicals}

e. {HNO₂ will generate bubbles of CO₂(g); answers “a” and “d” will cause precipitation from both K₂CO₃ and AgNO₃ so it would
    not clarify what the unknown is.}

16. a. Ni(s) + 2HBr(aq) → H₂(g) + NiBr₂(aq)  b. Al(s) + 3AgNO₃(aq) → 3Ag(s) + Al(NO₃)₃(aq)
    c. Fe(s) + Zn(NO₃)₂(aq) → no reaction  d. Mg(s) + SnSO₄(aq) → Sn(s) + MgSO₄(s)