CHEMICAL REACTION TYPES HANDOUT

SINGLE REPLACEMENT REACTION

REACTION DESCRIPTION

In these reactions, a free element reacts with a compound to form another compound and release one of the elements of the original compound in the elemental state. There are two different possibilities:

1. One cation (+ ion) replaces another.
2. One anion (- ion) replaces another.

REACTION FORMAT

1. A + BC → B + AC
2. A + BC → C + BA

REACTION GUIDELINES

1. In a single replacement reaction, atoms of one element replace the atoms of a second element in a compound. Whether one metal will replace another metal from a compound can be determined by the relative reactivities of the two metals. To help us determine this, an activity series of metals arranges metals in order of decreasing reactivity. A reactive metal will replace any metal listed below it in the activity series.

ACTIVITY SERIES OF METALS

METAL	SYMBOL
Lithium	Li
Rubidium	Rb
Potassium	K
Barium	Ba
Strontium	Sr
Calcium	Ca
Sodium	Na
Magnesium	Mg
Aluminum	Al
Zinc	Zn
Chromium	Cr
Iron	Fe
Cadmium	Cd
Cobalt	Co
Nickel	Ni
Tin	Sn
Lead	Pb
Hydrogen	H*
Antimony	Sb
Bismuth	Bi
Copper	Cu
Mercury	Hg
Silver	Ag
Platinum	Pt
Gold	Au

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

2. A nonmetal can also replace another nonmetal from a compound. This replacement is usually limited to the halogens (F_2, Cl_2, Br_2, and I_2). The activity of the halogens decreases as you go down the column on the periodic table.

REACTION GUIDELINES EXAMPLES

1. $Mg + Zn(NO_3)_2 \rightarrow Mg(NO_3)_2 + Zn$
   Mg replaces Zn; Mg is above Zn on the chart
   $Mg + 2\ AgNO_3 \rightarrow Mg(NO_3)_2 + 2\ Ag$
   Mg replaces Ag; Mg is above Ag on the chart
   $Mg + LiNO_3 \rightarrow$ No Reaction (NR)
   Mg cannot replace Li; Li is above Mg on the chart
2. $Cl_2 + 2\ NaBr \rightarrow 2\ NaCl + Br_2$

DOUBLE REPLACEMENT REACTION	REACTION DESCRIPTION	During double replacement, the cations and anions of two different compounds switch places.
	REACTION FORMAT	$AB + CD \rightarrow AD + CB$
	REACTION GUIDELINES	1. It is important that the formulas of the products be written correctly. If they are correct, balancing the equation is a simple task; if not, the equation will probably never balance. 2. In these reactions, there is never a change in ionic charge (if a reactant is a Lead II compound it will stay a Lead II compound as a product) 3. Sometimes you must determine if a reaction actually takes place? For example: Does a mixture of NaCl and H_2SO_4 react to give Na_2SO_4 and HCl, or rather, does a mixture of Na_2SO_4 and HCl react to give NaCl and H_2SO_4. Obviously we cannot test every reaction before we write the equation, but fortunately, there are certain conditions under which a reaction goes to completion (i.e. goes in one direction only). These are summarized below. A reaction takes place or tends to go to completion IF: • One of the products is a gas and is allowed to escape. • A covalent substance such as H_2O or NH_3 is formed. • An insoluble substance is formed. The first two of these are obvious if we are able to recognize which substances are gases. The most common inorganic gases are H_2, Cl_2, O_2, N_2, H_2S, HF, HCl, HBr, HI, CO, CO_2, SO_2, SO_3, NH_3, NO, NO2, N_2O, and HCN. The most difficult aspect of reactions of this type is the ability to recognize insoluble substances. Here are some solubility guidelines: 1. All nitrates and acetates are soluble. 2. All chlorides, bromides, and iodides, are soluble except those Pb^{2+}, Ag^{+}, and Hg^{+2}. 3. All sulfates are soluble except those of Ba^{2+}, Sr^{2+}, and Pb^{2+}. $CaSO_4$, Ag_2SO_4, and Hg_2SO_4 are slightly soluble. 4. All hydroxides are insoluble except those of group I in the periodic table, NH_4^{+}, and Ba^{2+}. $Ca(OH)_2$ and $Sr(OH)_2$ are slightly soluble. 5. All carbonates and phosphates are insoluble except those of group I and NH_4^{+}. Many hydrogen phosphates are soluble. 6. All sulfides are insoluble except those of group I and group II in the periodic table and NH_4^{+}. 7. H_2CO_3 decomposes into CO_2 and H_2O 8. H_2SO_3 decomposes into SO_2 and H_2O 9. NH_4OH decomposes into NH_3 and H_2O
	REACTION GUIDELINES EXAMPLES	1. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ 2. $CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$ (#7) 3. $Pb(NO_3)_2 + CuSO_4 \rightarrow PbSO_4 + Cu(NO_3)_2$

SYNTHESIS REACTIONS OR COMBINATION REACTIONS	REACTION DESCRIPTION	In these reactions, two different molecules or atoms unite to usually form a single substance.
	REACTION FORMAT	$A + B \rightarrow AB$
	REACTION GUIDELINES	1. Direct union of two elements will produce a binary compound. 2. Metallic oxides and carbon dioxide react to produce carbonates. 3. Binary salts and oxygen react to produce a chlorate. 4. Metallic oxides and water react to produce a base. 5. Nonmetallic oxides and water react to produce an acid.
	REACTION GUIDELINES EXAMPLES	1. $2\ Mg + O_2 \rightarrow 2\ MgO$ 2. $Na_2O + CO_2 \rightarrow Na_2CO_3$ 3. $2\ KCl + 3\ O_2 \rightarrow 2\ KClO_3$ 4. $Na_2O + H_2O \rightarrow 2\ NaOH$ 5. $N_2O_5 + H_2O \rightarrow 2\ HNO_3$
DECOMPOSITION REACTION	REACTION DESCRIPTION	During decomposition, one compound splits apart into two or more substances. These substances can be elements or simpler compounds.
	REACTION FORMAT	$AB \rightarrow A + B$
	REACTION GUIDELINES	1. Binary compounds breakdown into their elements. 2. Carbonates break down into an oxide and carbon dioxide 3. Chlorates break down to a binary salt and oxygen. 4. Bases bread down to oxide of the metal and water. 5. Acids break down to the oxide of the nonmetal plus water.
	REACTION GUIDELINES EXAMPLES	1. $2\ NaCl \rightarrow 2\ Na + Cl_2$ 2. $Na_2CO_3 \rightarrow Na_2O + CO_2$ 3. $Ba(ClO_3)_2 \rightarrow BaCl_2 + O_2$ 4. $Ca(OH)_2 \rightarrow CaO + H_2O$ 5. $2H_3PO_4 \rightarrow P_2O_5 + 3H_2O$

COMBUSTION REACTION	REACTION DESCRIPTION	There are two types of combustion reactions. 1. During a complete combustion reaction, a hydrocarbon (carbon – hydrogen containing compound) reacts with pure oxygen to produce carbon dioxide and water as products. 2. During a partial or incomplete combustion reaction, a hydrocarbon reacts with atmospheric oxygen to produce carbon dioxide, water, carbon monoxide, and carbon in the form of soot, smoke, or ash.
	REACTION FORMAT	1. $C_xH_y + O_2 \rightarrow CO_2 + H_2O$ 2. $C_xH_y + O_2 \rightarrow CO_2 + H_2O + CO + C$
	REACTION GUIDELINES	Complete combustion reactions burn in pure oxygen so that all of the carbon is converted into carbon dioxide. Partial combustion reactions take place under normal atmospheric conditions (approximately 30%). This impure concentration of oxygen doesn't convert all of the carbon into carbon dioxide; we instead end up with all of the crap left over when hydrocarbons burn. Complete combustion ALWAYS gives the same two products (CO_2 and H_2O). Incomplete or partial combustion ALWAYS forms the same four products (CO_2, H_2O, CO, and C). In balancing partial combustion reactions there can be more than one correct ratio of reactants and products. There is no real way to predict which answer is the most accurate, it depends on the percent of oxygen present at the burn. Any answer that balances the equation is correct.
	REACTION GUIDELINES EXAMPLES	Complete Combustion: $2\ C_6H_6 + 15\ O_2 \rightarrow 12\ CO_2 + 6\ H_2O$ Partial Combustion: $C_6H_6 + 3\ O_2 \rightarrow CO_2 + 3\ H_2O + CO + 4\ C$
ACID/BASE REACTIONS	REACTION DESCRIPTION	In an acid/base reaction, there an acid combines with a base to form an ionic compound and water.
	REACTION FORMAT	ACID + BASE → SALT + WATER
	REACTION GUIDELINES	Acid/Base reactions are basically specialized double replacement reactions. Where the metal from the acid switches places with the metal from the base to form a salt and the water. Acids are usually compounds that contain loosely held hydrogen ions. They are composed of the H^+ cation forming a bond with an anion. Acids are named according to the following three rules: 1. Binary acids are named with the prefix *hydro-* and the suffix *–ic* added to the root. *(Hydrogen sulfide ⇒ hydrosulfuric acid)* 2. Ternary acids (polyatomic ion) ending in *–ite*, the acid is named with the suffix *–ous* . *(Hydrogen sulfite ⇒ sulfurous acid)* 3. Ternary acids ending in *–ate*, the acid is named with the suffix *–ic* (no *hydro-* prefix). *(Hydrogen sulfate ⇒ sulfuric acid)* Bases are compounds that contain loosely held hydroxide ions. They are composed of a metal cation forming a bond with the OH^- anion. Some bases, simply contain ions which can react with the available Hydrogen ions (HCO_3^{-1} can react with H^+ to form a neutral compound)
	REACTION GUIDELINES EXAMPLES	1. $HCl + NaOH \rightarrow NaCl + H_2O$ 2. $H_2SO_4 + NaHCO_3 \rightarrow Na_2SO_4 + H_2O + CO_2$

OXIDATION/REDUCTION REACTION (REDOX)	REACTION FORMAT	• Oxidation can be defined as "an increase in oxidation number." • Reduction can be defined as "a decrease in oxidation number."
	REACTION GUIDELINES	**1. Redox reactions primarily involve the transfer of electrons between two chemical species. The compound that loses an electron is said to be oxidized, the one that gains an electron is said to be reduced.** • There are also specific terms that describe the specific chemical species. A compound that is oxidized is refered to as a reducing agent, while a compound that is reduced is referred to as the oxidizing agent. **2. In these reactions, the oxidation numbers of the** reactants change**.** • For ex: $2Fe^{3+} + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+}$ (8^+ each side of the eqn) • The iron (III) + tin (II) have reacted to give iron (II) + tin (IV) of course, this rxn is carried out in the presence of Hydrochloric Acid, but the redox rxn is only between the iron (III) and tin (II). **3. Now, a redox reaction is the release and uptake of electrons.** • So, the Fe^{3+} is <u>reduced</u> to Fe^{2+}, and the Sn^{2+} is <u>oxidized</u> to Sn^{4+}. • Sn^{2+} donated electrons to the Fe^{3+} (an electron transfer took place). **<u>Redox</u> <u>reactions</u>** are the transfer of electrons from one reactant to another... • When there is **<u>oxidation</u>**, there is also **<u>reduction</u>**. • The substance which <u>loses</u> electrons is <u>oxidized</u>. • The substance which <u>gains</u> electrons is <u>reduced</u>. **4. Sometimes it is easier to see the transfer of electrons in the system if it is split into definite steps. This will be <u>oxidation</u> of one substance and <u>reduction</u> of the other substance.** **$2Fe^{3+} + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+}$** **Split into 2 separate steps.** • $2Fe^{3+} + 2e^- \rightarrow 2Fe^{2+}$ (<u>reduction</u>) (6+) + (2-) → (4+) (balanced for charges) • $Sn^{2+} \rightarrow Sn^{4+} + 2e^-$ (<u>oxidation</u>) (2+) -> (4+) + (2-) • **Add the 2 half eqns:** $2Fe^{3+} + 2e^- + Sn^{2+} \rightarrow 2Fe^{2+} + Sn^{4+} + 2e^-$ **The electrons cancel each other out, so eqn is:** $2Fe^{3+} + Sn^{2+} \rightarrow 2F^{2+} + Sn^{4+}$ **By breaking down the equation into half cells, the oxidation or reduction of each chemical can be determined.**
	REACTION GUIDELINES EXAMPLES	1. $2Ca + O_2 \rightarrow 2CaO$ • $2Ca^0 \rightarrow 2\ Ca^{+2} + 4e^-$ (Oxidation) • $O_2^0 + 4e^- \rightarrow 2\ 0^{-2}$ (Reduction) 2. $2Na + Cl_2 \rightarrow 2NaCl$ • $2Na^0 \rightarrow 2Na^{+1} + 2e^-$ (Oxidation) • $Cl_2^0 + 2e^- \rightarrow 2\ Cl^{-1}$ (Reduction) 3. $CO_2 + H_2 \rightarrow CO + H_2O$ • $C^{+4} + 2e^- \rightarrow C^{+2}$ (Reduction) • $H_2^0 \rightarrow 2H^{+1} + 2e^-$ (Oxidation)