

Qualitative Analysis

Chemicals that you must know the appearance and properties of:

Potassium Permanganate

Potassium Chromate

Potassium Dichromate

Cobalt (II) Chloride

Iron Thiocyanate Complex Ion

Iron (III) Chloride

Silver (I) Nitrate

Sodium Chloride

Ammonium Chloride

Copper (II) Sulfate

The Classic Qualitative Tests

Lugol's Solution

Benedict's Solution

Phenolphthalein Solution

Solubility in water versus alcohol

Solubility

	NaCl	Na ₂ S	Na ₂ SO ₄	NaOH
AgNO ₃				
BaCl ₂				
NH ₄ Cl				
HCl				
Pb(NO ₃) ₂				

Gases

	Color	Smell	Splint Test	Special Tests
Nitrogen				
Oxygen				
Hydrogen				
Carbon Dioxide				
Ammonia				
Nitrogen Dioxide				

Flame Tests

Red	
Orange	
Yellow	
Green	
Blue	
Indigo	
Violet	

CLASSES OF CHEMICAL REACTIONS

Combination or Synthesis: $A + B \rightarrow AB$

- A) Metal oxides will react with water to form bases
- B) Some nonmetal oxides will react with water to form ternary acids
- C) Many elements will react with oxygen to form oxides
- D) Metals can combine with nonmetals to form ionic compounds

Decomposition: $AB \rightarrow A + B$

- A) Metallic carbonates, when heated, form metal oxides, plus carbon dioxide
- B) Many metallic hydroxides, when heated, decompose into metallic oxides and water
- C) Metallic chlorates, when heated, decompose into metallic chlorides and oxygen
- D) Some acids, when heated, decompose into non-metallic oxides and water
- E) Some oxides, when heated decompose
- F) Some decomposition reactions are produced by electricity
- G) Ammonium salts decompose to give off ammonia gas

Single Replacement: $A + BC \rightarrow AC + B$ or $D + BC \rightarrow C + BD$

- A) An active metal will replace hydrogen in water
- B) A metal may replace hydrogen in an acid
- C) A metal in a compound may be replaced by a more active metal
- D) A halogen will replace a halogen below it in the Periodic Table

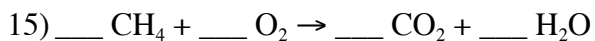
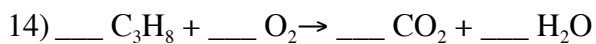
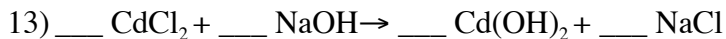
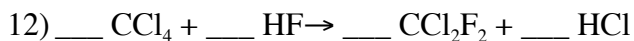
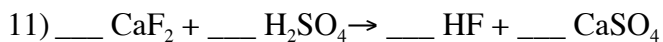
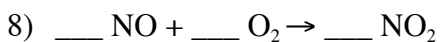
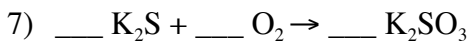
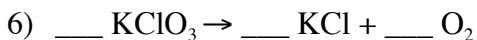
Double Replacement: $AB + CD \rightarrow AD + CB$

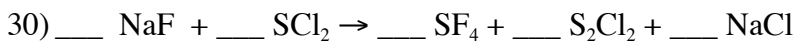
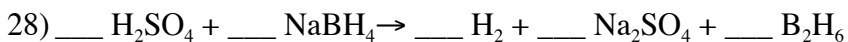
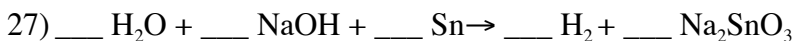
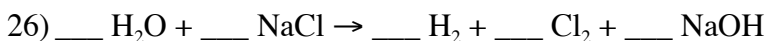
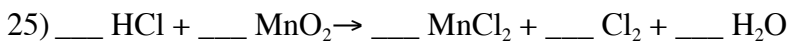
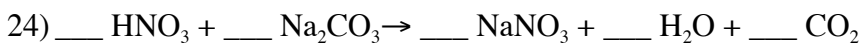
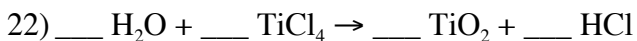
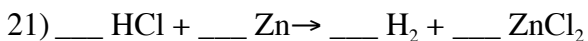
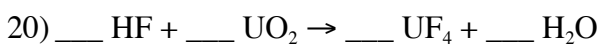
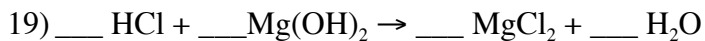
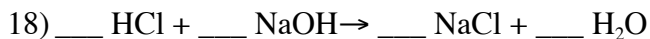
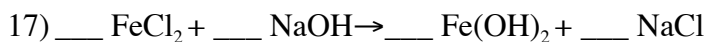
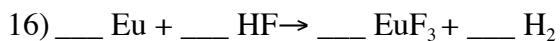
- A) An acid and a base will react to form a salt and water
- B) Two compounds may react to form a precipitate
- C) A metal oxide may react with an acid to form a salt and water
- D) Two compounds may react to form a gas

Combustion: $X + O_2 \rightarrow$

- A) Hydrocarbons can combust in oxygen to make carbon dioxide and water
- B) Metals can combine with oxygen to produce oxides.
- C) Non metals can combust to give oxides.

Balance the following equations by placing the appropriate coefficient on the lines.





Precipitation Reactions

Table 3.1 Solubility rules for inorganic compounds

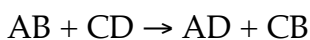
Soluble compounds	Insoluble compounds
compounds of Group 1 elements	carbonates (CO_3^{2-}), chromates (CrO_4^{2-}), oxalates ($\text{C}_2\text{O}_4^{2-}$), and phosphates (PO_4^{3-}), <u>except</u> those of the Group 1 elements and NH_4^+
ammonium (NH_4^+) compounds	sulfides (S^{2-}), <u>except</u> those of the Group 1 and 2 elements and NH_4^+
chlorides (Cl^-), bromides (Br^-), and iodides (I^-) <u>except</u> those of Ag^+ , Hg_2^{2+} , and Pb^{2+} *	hydroxides (OH^-) and oxides (O^{2-}), <u>except</u> those of the Group 1 and 2 elements†
nitrates (NO_3^-), acetates (CH_3CO_2^-), chlorates (ClO_3^-), and perchlorates (ClO_4^-)	
sulfates (SO_4^{2-}), <u>except</u> those of Ca^{2+} , Sr^{2+} , Ba^{2+} , Pb^{2+} , Hg_2^{2+} , and Ag^+ ‡	

* PbCl_2 is slightly soluble.

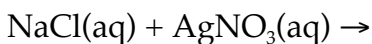
† $\text{Ca}(\text{OH})_2$ and $\text{Sr}(\text{OH})_2$ are sparingly (slightly) soluble; $\text{Mg}(\text{OH})_2$ is only very slightly soluble.

‡ Ag_2SO_4 is slightly soluble.

Think of a double replacement reaction.



We must consider if only one set of these products is of interest to us.

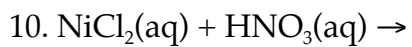
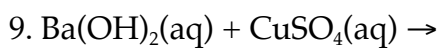
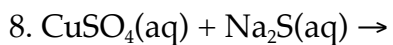
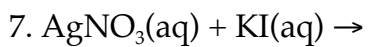
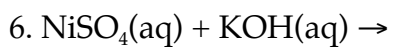
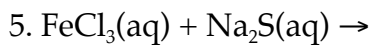
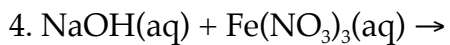
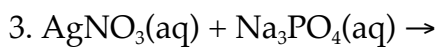
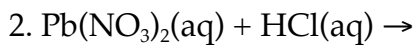
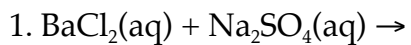


First the molecular equation:

Second the complete ionic equation:

Finally the net ionic:

Write molecular, complete ionic, and net ionic equations for the following:



Electrochemistry

What is it?

Redox Reaction

Oxidation

Why do we call it oxidation?

Reduction

Why do we call it reduction?

Half Reaction

Who is an oxidizing agent? Why?

Who is a reducing agent? Why?

How do we keep track of who is oxidized and who is reduced?

Oxidation Number:

Rules for Assigning Oxidation Numbers

1.

2.

3.

4.

5.

What is the oxidation number for chlorine in the following situations:

a. Cl_2 _____d. HClO_2 _____b. HCl _____e. HClO_3 _____c. HOCl _____f. HClO_4 _____

Assign an oxidation number to NITROGEN in each of the following compounds:

a. Li_3N _____f. NO _____b. N_2 _____g. HNO_3 _____c. N_2O _____h. NH_3 _____d. NO_3^- _____i. NO_2^- _____e. NO_2 _____j. N_2H_4 _____

Assign oxidation numbers to all the atoms in the following compounds:

 Fe_3O_4 H_2O_2 NaH BeH_2

Balancing Redox Equations

Rules for Balancing Redox Equations in Acid

1.

2.

3.

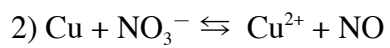
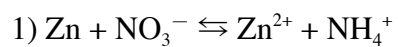
4.

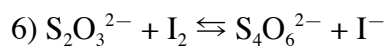
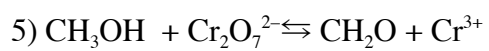
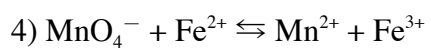
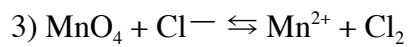
5.

6.

7.

Balance the following redox equations in acid:

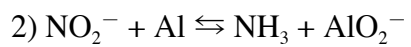
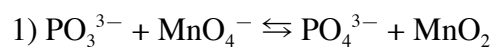


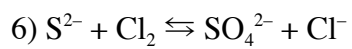
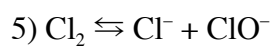
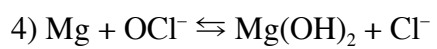
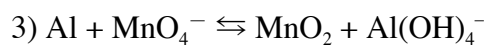


Rules for Balancing Redox Equations in Base

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.

Balance the following redox equation in base:





The Reactions Question

What are they testing for?

To dissociate or not to dissociate? That is the question

Strong Acid/ Weak Acid/ The H_2SO_4 dilemma

Words for solids

Special Words

THE MAJOR TYPES OF REACTIONS**Synthesis/ Combination**

a) Magnesium ribbon is burned in oxygen.

(Is this a redox reaction?)

b) Lithium metal is burned in air.

(Why doesn't the product dissociate?)

c) Solid calcium oxide is exposed to a stream of carbon dioxide gas.

(What would this product look like if it were placed in water?)

Metal oxide and water

a) Powdered strontium oxide is added to distilled water.

(Is this product acidic, basic or neutral?)

b) Solid cesium oxide is added to water.

(Is this product acidic, basic or neutral?)

c) Calcium oxide powder is added to distilled water.

(Why doesn't this product dissociate?)

Non-metal oxide and water

a) Carbon dioxide is bubbled through a sample of distilled water.

(Why doesn't this product dissociate?)

b) Solid dinitrogen pentoxide is added to water.
(Will this product be associated or dissociated?)

c) Sulfur dioxide gas is bubbled into distilled water.
(Will this product be associated or dissociated?)

Decomposition

a) A solution of hydrogen peroxide is exposed to strong sunlight.
(What is the role sunlight here?)

b) Powdered magnesium carbonate is heated strongly.
(How can you confirm the identity of the gas produced?)

c) Solid ammonium carbonate is heated.
(How can you confirm the identity of the gas produced?)

d) Solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst.
(What is a good test for oxygen gas?)

e) Solid sodium hydrogen carbonate (sodium bicarbonate) is strongly heated.
(How can you confirm the identity of the gas produced?)

Acid/Base

a) Equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed. (Is the product of this acidic or basic or neutral?)

- b) Excess hydrobromic acid solution is added to a solution of potassium hydrogen carbonate. (Why isn't potassium included in this equation?)

- c) Solid zinc carbonate is added to 1.0 M sulfuric acid.
(What are the bubbles made of?)

- d) A solution of potassium hydroxide is added to solid ammonium chloride.
(Why does the product smell?)

- e) An excess of hydrochloric acid is added to solid zinc sulfide.
(Why doesn't H_2S dissociate)

- f) Solutions of potassium hydroxide and propanoic acid are mixed.

- g) A 0.02 M hydrochloric acid solution is mixed with an equal volume of a 0.01 M calcium hydroxide solution. (Is the product acidic, basic, or neutral?)

Lewis Acid/Base

- a) Samples of boron trichloride gas and ammonia gas are mixed.
(What is the Lewis acid and what is the Lewis base?)

- b) Phosphine (phosphorus trihydride) gas is bubbled into liquid boron trichloride.
(Why isn't this a replacement reaction?)

Precipitation

- a) Solutions of silver nitrate and lithium bromide are mixed.
(Who are the spectator ions here?)

- b) A solution of sodium iodide is added to a solution of lead (II) acetate.
(What color is the lead product?)

- c) A solution of potassium phosphate is mixed with a solution of calcium acetate.
(Where will you see the product of this reaction?)

- d) A solution of copper (II) sulfate is added to a solution of barium hydroxide.
(What color is the copper (II) sulfate?)

Single Replacement

- a) A small piece of sodium metal is added to distilled water.
(Is the product acidic, basic, or neutral?)

- b) Chlorine gas is bubbled through a solution of potassium bromide.
(Identify the oxidation number of chlorine in every species)

- c) A piece of copper wire is placed in a solution of silver nitrate.
(What type of color change will you see here?)

- d) A small piece of calcium metal is added to hot distilled water.
(Why use hot water?)

e) A bar of strontium metal is immersed in a 1.0 M copper (II) nitrate solution.
(What color is the copper when you finish?)

f) A strip of copper is immersed in dilute nitric acid.
(What color is the copper when you finish?)

g) Carbon monoxide gas is passed over hot iron (III) oxide.
(Who is the oxidizing agent?)

Electron Transfer in Solution

a) Solutions of tin (II) chloride and iron (III) chloride are mixed.
(Why isn't tin (I) formed?)

b) A solution of tin (II) nitrate is added to a solution of silver nitrate.
(Who is oxidized and who is reduced?)

Big Ugly Redox

a) Acidified solutions of potassium permanganate and iron (II) nitrate are mixed together. (What color is the manganese compound before and after the reaction?)

b) A solution of iron (II) chloride is added to an acidified solution of sodium dichromate. (What is the oxidation number of chromium before and after reaction?)

c) Hydrogen peroxide solution is added to acidified potassium iodide solution.
(Who is reduced?)

Disproportionation

- a) Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
(Who is the oxidizing agent?)

- b) A solution of sodium bromide is added to an acidified solution of potassium bromate.
(Assign oxidation numbers to bromine in all species)

Complex Ions

- a) Excess sodium cyanide solution is added to a solution of silver nitrate.

- b) Excess concentrated ammonia solution is added to a solution of nickel (II) sulfate.

- c) Excess concentrated aqueous ammonia is added to solid silver chloride.

- d) Excess concentrated hydrochloric acid is added to a 1.0 M solution of cobalt (II) chloride. (What color change would you observe?)

e) Excess potassium hydroxide solution is added to a solution of aluminum nitrate.
(What color would phenolphthalein be in this solution)

f) A drop of potassium thiocyanate solution is added to a solution of iron (III) nitrate.
(What color is the product?)

Organic Combustion

a) Butanol is burned in air.
(How many moles of oxygen are need for one mole of butanol?)

Organic Addition

a) Ethene (ethylene) gas is bubbled through a solution of bromine.
(What color change would you expect to see in this reaction?)

Formation of Esters

a) Ethanol and formic acid (methanoic acid) are mixed and warmed.
(Why warm it?)

b) Pure methyl alcohol and pure acetic acid are mixed.
(Is this a dehydration reaction?)

The following is a former AP question:

The identity of an unknown solid is to be determined. The compound is one of the seven salts in the following table.

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

Use the results of the following observations or laboratory tests to explain how each compound in the table may be eliminated or confirmed. The tests are done in sequence from (a) through (e).

- (a) The unknown compound is white. In the table below, cross out the two compounds that can be eliminated using this observation. Be sure to cross out these same two compounds in the tables in parts (b), (c), and (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (b) When the unknown compound is added to water, it dissolves readily. In the table below, cross out the two compounds that can be eliminated using this test. Be sure to cross out these same two compounds in the tables in parts (c) and (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (c) When $\text{AgNO}_3(aq)$ is added to an aqueous solution of the unknown compound, a white precipitate forms. In the table below, cross out each compound that can be eliminated using this test. Be sure to cross out the same compound(s) in the table in part (d).

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (d) When the unknown compound is carefully heated, it loses mass. In the table below, cross out each compound that can be eliminated using this test.

$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	CaCO_3	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
NaCl	BaSO_4	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	

- (e) Describe a test that can be used to confirm the identity of the unknown compound identified in part (d). Limit your confirmation test to a reaction between an aqueous solution of the unknown compound and an aqueous solution of one of the other soluble salts listed in the tables. Describe the expected results of the test; include the formula(s) of any product(s).