

## AP Chemistry Reaction Questions

Directions: Give the formulas to show the reactants and the products for the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solution as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In ALL cases a reaction occurs. You need not balance.

Note: the reactions are not broken down by type on the actual AP exam. Score one point for correct reactants and 2 points for correct products.

### I. DOUBLE REPLACEMENT

Solubility rules that apply to water solution:

- (1) All alkali metal (lithium, sodium, potassium, rubidium, and cesium) compounds are soluble.
- (2) All acetate, ammonium, chlorate, and nitrate compounds are soluble.
- (3) Chlorides, bromides, and iodides are soluble except silver, lead, and mercury(I)
- (4) Sulfates are soluble except silver, mercury(I), lead(II), calcium, strontium, and barium.
- (5) Sulfides are soluble only for alkali metals, alkaline earth metals, and ammonium.
- (6) Hydroxide (and oxides) are insoluble except for (1) above as well as ammonium, strontium, and barium.
- (7) Phosphates, carbonates, and silicates are insoluble except for (1) above as well as ammonium.

These ions generally form precipitates:  $\text{Pb}^{2+}$   $\text{Ag}^+$   $\text{OH}^-$   $\text{CO}_3^{2-}$   $\text{PO}_4^{3-}$   $\text{S}^{2-}$   $\text{Hg}_2^{2+}$

These ions generally do not form precipitates even when combined with the above ions:

$\text{NH}_4^+$   $\text{Na}^+$   $\text{K}^+$   $\text{Cl}^-$   $\text{NO}_3^-$   $\text{SO}_4^{2-}$

Some exceptions which do precip.:  $\text{CaSO}_4$ ,  $\text{SrSO}_4$ ,  $\text{BaSO}_4$ ,  $\text{PbCl}_2$ ,  $\text{AgCl}$ ,  $\text{PbSO}_4$ ,  $\text{Hg}_2\text{Cl}_2$

Note: there are some alkali metal compounds that are insoluble. These are rather exotic compounds and can be safely ignored in the context of this handout.

1. Dilute sulfuric acid is added to a solution of barium acetate.
2. Ammonium chloride crystals are added to a solution of sodium hydroxide.
3. A precipitate is formed when solutions of trisodium phosphate and calcium chloride are mixed.
4. Equal volumes of 0.1 M hydrochloric acid and 0.1 M disodium hydrogen phosphate are mixed.
5. Hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.
6. Solutions of silver nitrate and sodium chromate are mixed.
7. Solutions of sodium fluoride and dilute hydrochloric acid are mixed.
8. A saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.
9. A solution of ammonium sulfate is added to a potassium hydroxide solution.
10. A solution of ammonium sulfate is added to a saturated solution of barium hydroxide.
11. A drop of potassium thiocyanate is added to a solution of iron(III) chloride.
12. Dilute sulfuric acid is added to solid calcium fluoride.
13. Dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.
14. A solution of ammonium chloride is added to a dilute solution of mercury(I) nitrate.
15. Solid cupric sulfide is warmed with 6 N nitric acid.
16. A 50 milliliter sample of 0.10 M hydrochloric acid is added slowly with stirring to a 50 milliliter sample of 0.10 M sodium carbonate solution.
17. Hydrogen sulfide is bubbled through a solution of silver nitrate.
18. Excess silver acetate is added to a solution of trisodium phosphate.
19. Solid sodium cyanide is added to water
20. Manganese(II) nitrate solution is mixed with sodium hydroxide solution.
21. Equal volumes of dilute equimolar solutions of sodium carbonate and hydrochloric acid are mixed.
22. Solid barium peroxide is added to cold dilute sulfuric acid.
23. Dilute acetic acid solution is added to solid magnesium carbonate.
24. Solid magnesium nitride is added to excess deuterium oxide.

25. Gaseous hydrofluoric acid reacts with solid silicon dioxide.
26. Equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.
27. A saturated solution of calcium hydroxide is added to a solution of magnesium chloride.
28. Solid silver sulfide is warmed with dilute nitric acid.
29. Hydrogen sulfide gas is added to a solution of cadmium nitrate.
30. Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.
31. A solution of sodium sulfide is added to a solution of zinc nitrate.
32. Gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.
33. Dilute hydrochloric acid is added to a solution of potassium carbonate.
34. Dilute sulfuric acid is added to a solution of barium chloride.
35. A solution of sodium hydroxide is added to a solution of ammonium chloride.
36. Solutions of zinc sulfate and sodium phosphate are mixed.
37. Solutions of silver nitrate and lithium bromide are mixed.
38. Excess hydrochloric acid solution is added to a solution of potassium sulfite.
39. Solutions of sodium iodide and lead nitrate are mixed.
40. A solution of ammonia is added to a solution of ferric chloride.
41. Solutions of silver nitrate and sodium chromate are mixed.
42. Solutions of copper(II) sulfate and barium hydroxide.
43. An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.
44. Solutions of tri-potassium phosphate and zinc nitrate are mixed.
45. Excess concentrated sulfuric acid is added to solid calcium phosphate.
46. Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.
47. Solid ammonium carbonate is added to a saturated solution of barium hydroxide.

## II. ACID-BASE NEUTRALIZATIONS

<u>Strong Acids</u>		<u>Weak Acids</u>		<u>Soluble</u>	
<u>Arrhenius Bases</u>					
HClO <sub>4</sub>	HCl	HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub>	H <sub>2</sub> S	NaOH	LiOH
HClO <sub>3</sub>	HBr	H <sub>3</sub> PO <sub>4</sub>	HF	KOH	Ca(OH) <sub>2</sub>
HNO <sub>3</sub>	HI	H <sub>2</sub> CO <sub>3</sub>	HNO <sub>2</sub>	RbOH	Sr(OH) <sub>2</sub>
H <sub>2</sub> SO <sub>4</sub>				CsOH	Ba(OH) <sub>2</sub>

Additional weak acids - protonated nitrogen cations such as NH<sub>4</sub><sup>+</sup>, CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>, etc.; highly charged metal cations such as Fe<sup>3+</sup>, Al<sup>3+</sup>, Cr<sup>3+</sup>; and oxides of nonmetals (acid anhydrides) such as CO<sub>2</sub>, SO<sub>2</sub>, SO<sub>3</sub>, NO<sub>2</sub>, ClO<sub>3</sub>, etc. Note: the nonmetal retains its oxidation number.

Additional strong bases - oxides of group I and II cations (Na<sub>2</sub>O, BaO, CaO, etc.). They react with water to give the cation and hydroxide - Na<sub>2</sub>O + H<sub>2</sub>O → 2 Na<sup>+</sup> + OH<sup>-</sup>. The hydride ion (H<sup>-</sup>) gives OH<sup>-</sup> and H<sub>2</sub> in water. The nitride ion (N<sup>3-</sup>) gives OH<sup>-</sup> and NH<sub>3</sub> in water. The carbide ion (C<sup>4-</sup>) gives OH<sup>-</sup>, acetylene (C<sub>2</sub>H<sub>2</sub>), and H<sub>2</sub> in water.

Additional weak bases - most all anions (PO<sub>4</sub><sup>3-</sup>, F<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, CO<sub>3</sub><sup>2-</sup>, SO<sub>3</sub><sup>2-</sup>). An example equation would be: PO<sub>4</sub><sup>3-</sup> + H<sub>2</sub>O → HPO<sub>4</sub><sup>2-</sup> + OH<sup>-</sup>

Sulfites give sulfur dioxide in acid solution: SO<sub>3</sub><sup>2-</sup> + 2 H<sup>+</sup> → SO<sub>2</sub>(g) + H<sub>2</sub>O

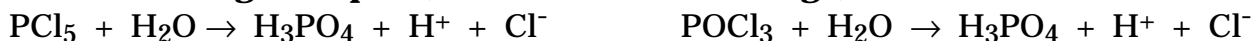
Carbonates give carbon dioxide in acid solution: CO<sub>3</sub><sup>2-</sup> + 2 H<sup>+</sup> → CO<sub>2</sub>(g) + H<sub>2</sub>O

Spectator ions are usually Group I and II cations (unless they form a precipitate) and anions of strong bases such as Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, ClO<sub>4</sub><sup>-</sup>.

HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> can also be written as CH<sub>3</sub>COOH  
NH<sub>4</sub>OH is written as NH<sub>3</sub> + H<sub>2</sub>O

H<sub>2</sub>CO<sub>3</sub> is written as H<sub>2</sub>O + CO<sub>2</sub>  
H<sub>2</sub>SO<sub>3</sub> is written as SO<sub>2</sub> + H<sub>2</sub>O

### Two Interesting Examples (not acids, but close enough)



### Hydrolysis

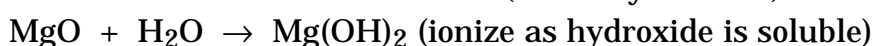
- A. Salts of weak acids:  $\text{A}^- + \text{H}_2\text{O} \rightarrow \text{HA} + \text{OH}^-$   
 $\text{B}^{2-} + \text{H}_2\text{O} \rightarrow \text{HB}^- + \text{OH}^-$  (first step ONLY!)
- B. Salts of weak bases:  $\text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+$
- C. Salts of transition metals:  $\text{M}^{3+} + \text{H}_2\text{O} \rightarrow \text{M}(\text{OH})^{2+} + \text{H}_3\text{O}^+$  (first step ONLY!)

### Amphoterism

Zn(OH)<sub>2</sub>, Al(OH)<sub>3</sub>, Cr(OH)<sub>3</sub>  $\text{M}(\text{OH})^x + \text{OH}^- \rightarrow \text{M}(\text{OH})^{x-1}$  (or add OH<sup>-</sup> to coordination number)

### Anhydrides

metal oxides + water → bases (metal hydroxides)



non-metal oxide + water → acids (oxidation number of nonmetal is the same in the acid as in the oxide). N<sub>2</sub>O<sub>5</sub> + H<sub>2</sub>O → H<sup>+</sup> + NO<sub>3</sub><sup>-</sup> (Oxidation number is +5; note that nitric acid is a strong acid and is fully ionized in solution. Weak acids should be left as molecules.)

1. A solution of sulfuric acid is added to a solution of barium hydroxide until the same number of moles of each compound has been added.
2. A solution of sodium hydroxide is added to a solution of sodium dihydrogen phosphate until the same number of moles of each compound has been added.
3. Dilute nitric acid is added to crystals of pure calcium oxide.
4. A solution of sodium hydroxide is added to a solution of calcium hydrogen carbonate until the number of moles of sodium hydroxide added is twice the number of moles of calcium hydrogen carbonate.
5. Hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.
6. Carbon dioxide gas is bubbled through a concentrated solution of calcium hydroxide.
7. Acetic acid solution is added to a solution of sodium hydrogen carbonate.
8. Dilute solutions of lithium hydroxide and hydrobromic acid are mixed.
9. Sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.
10. Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.
11. A solution of ammonia is added to a dilute solution of acetic acid.
12. Excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.
13. Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.
14. Equal volumes of 0.1 M sulfuric acid and 0.1 M potassium hydroxide are added together.
15. Solutions of ammonia and hydrofluoric acid are mixed.
16. Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.
17. Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
18. Equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed.
19. Ammonia gas is bubbled into a solution of ethanoic (acetic) acid.

### III. COMPLEX IONS

A complex ion is an ion containing one or more molecules or ions bonded to a central metal ion. Common complex ions are:  $\text{Cu}(\text{NH}_3)_4^{2+}$ ,  $\text{Ni}(\text{NH}_3)_4^{2+}$ ,  $\text{Zn}(\text{NH}_3)_4^{2+}$ ,  $\text{Ag}(\text{NH}_3)_2^+$ ,  $\text{FeSCN}^{2+}$ ,  $\text{Pb}(\text{OH})_3^-$ ,  $\text{Al}(\text{OH})_4^-$ ,  $\text{Zn}(\text{OH})_2^{2-}$ ,  $\text{Cr}(\text{OH})_4^-$ . Some transition metals that form complexes and their coordination number:  $\text{Cu}^{2+}$  (4),  $\text{Al}^{3+}$  (6),  $\text{Fe}^{3+}$  (6),  $\text{Ag}^+$  (2). When in doubt as to the coordination number, double the charge on the ion. Common ligands:  $\text{NH}_3$ ,  $\text{OH}^-$ ,  $\text{I}^-$ ,  $\text{CO}$ . Much of the behavior of the reactions below can be rationalized on the basis of Lewis acid base theory. For example, the answer to number ten is:  $\text{NH}_3 + \text{Cu}^{2+} \rightarrow \text{Cu}(\text{NH}_3)_4^{2+}$ . The  $\text{NH}_3$ , with a unshared electron pair, is electron-rich and can donate an electron pair (the Lewis base). The  $\text{Cu}^{2+}$  is electron-deficient and can accept electron pairs (the Lewis acid).

1. Excess dilute nitric acid is added to a solution containing the tetraminecadmium(II) ion.
2. Pellets of aluminum metal are added to a solution containing an excess of sodium hydroxide. (see #18) (See #12 for an aluminum solution rather than solid Al.)
3. An excess of ammonia gas is bubbled through a solution saturated with silver chloride.
4. A suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.
5. Silver chloride is dissolved in excess ammonia solution.
6. Sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.
7. A concentrated solution of ammonia is added to a suspension of zinc hydroxide.
8. Freshly precipitated zinc hydroxide is treated with concentrated (15 M) ammonia solution.
9. A 3 M sodium hydroxide solution is added in excess to a solution of zinc chloride.
10. Concentrated (15 M) ammonia solution is added in excess to a solution of copper(II) sulfate.
11. Concentrated (15 M) ammonia is added in excess to copper(II) nitrate.
12. An excess of sodium hydroxide solution is added to a solution of aluminum chloride.
13. Dilute hydrochloric acid is added to a solution of diammine silver(I) nitrate.
14. A suspension of copper(II) hydroxide is treated with an excess of ammonia water.
15. A solution of diammine silver(I) chloride is treated with dilute nitric acid.
16. An excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.
17. Excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.
18. Excess concentrated sodium hydroxide solution is added to solid aluminum. (see#2)
19. A concentrated solution of ammonia is added to a solution of copper(II) chloride.
20. A solution of ammonium thiocyanate is added to a solution of iron(III) chloride.
21. Solid aluminum oxide to excess sodium hydroxide.
22. Excess concentrated ammonia added to solution of barium hydroxide.
23. An excess of nitric acid solution is added to a solution of tetraaminecopper(II) sulfate.
24. Excess concentrated ammonia solution is added to a suspension of silver chloride.

### IV. COMBUSTION

Compounds containing carbon and hydrogen (and oxygen) burn in oxygen to produce carbon dioxide and water. If sulfur is present,  $\text{SO}_2$  is formed. If nitrogen is present,  $\text{NO}_2$  is formed.

1. Excess oxygen is mixed with ammonia in the presence of platinum.
2. Gaseous silane,  $\text{SiH}_4$ , is burned with oxygen.
3. Ethanol is completely burned in the air.
4. Glucose is completely burned in oxygen.
5. Lithium metal is burned in air.
6. The hydrocarbon hexane is burned in excess oxygen.
7. Gaseous diborane,  $\text{B}_2\text{H}_6$ , is burned in excess oxygen.
8. Propanol is burned completely in air.
9. Carbon disulfide vapor is burned in excess oxygen.
10. Ethanol is burned in oxygen.

## V. ANHYDRIDES

1. Water is added to a sample of pure phosphorus tribromide.
2. Water is added to a sample of pure sodium hydride.
3. Dinitrogen trioxide gas is bubbled into water.
4. Solid phosphorus pentachloride is added to excess water.
5. Solid lithium oxide is added to excess water.
6. Solid sodium sulfite is added to water.
7. Ammonia gas and carbon dioxide gas are added to water.
8. Solid magnesium nitride is hydrolyzed.
9. Gaseous hydrogen chloride is dissolved in water.
10. Phosphorus tribromide is added to water.
11. Excess water is added to solid calcium hydride.
12. Liquid phosphorus trichloride is poured into a large excess of water.
13. Solid sodium carbide is added to an excess of water.
14. Solid aluminum nitrate is dissolved in water.
15. Trisodium phosphate crystals are added to water.
16. Phosphorus(V) oxytrichloride is added to water.
17. Solid sodium oxide is added to water.
18. Solid dinitrogen pentoxide is added to water.
19. Solid lithium hydride is added to water.
20. Solid potassium oxide is added to water.
21. Water is added to a sample of solid magnesium nitride.
22. Solid barium oxide is added to distilled water.
23. Solid calcium hydride is added to distilled water.
24. Drops of liquid dinitrogen trioxide are added to distilled water.

## VI. REDOX

Manganese		Chromium		Oxygen		Nitrogen		Sulfur	
$\text{MnO}_4^{2-}$	+7	$\text{Cr}_2\text{O}_7^{2-}$	+6	$\text{O}_2$	0	$\text{NO}_3^-$	+5	$\text{SO}_4^{2-}$	+6
$\text{MnO}_2$	+4	$\text{CrO}_4^{2-}$	+6	$\text{H}_2\text{O}_2$	-1	$\text{NO}_2$	+4	$\text{SO}_2$	+4
$\text{Mn}^{2+}$	+2	$\text{Cr}^{3+}$	+3	$\text{H}_2\text{O}$	-2	$\text{NO}$	+2	$\text{SO}_3^{2-}$	+4
		$\text{Cr}(\text{OH})_3$	+3			$\text{N}_2\text{O}$	+1	$\text{S}$	0
						$\text{N}_2$	0	$\text{S}^{2-}$	-2

The nitrogen in ammonia ( $\text{NH}_3$ ) is a -3 oxidation state.

### Common Oxidizing Agents

nitrate	$\text{NO}_3^-$
permanganate	$\text{MnO}_4^-$
hydrogen peroxide	$\text{H}_2\text{O}_2$
dichromate/chromate	$\text{Cr}_2\text{O}_7^{2-}$ , $\text{CrO}_4^{2-}$
iodate	$\text{IO}_3^-$
tin(IV)	$\text{Sn}^{4+}$
iron(III)	$\text{Fe}^{3+}$
difluorine / dichlorine	$\text{F}_2$ / $\text{Cl}_2$

### Reduced to

$\text{NO}_2$ (with conc. acid), $\text{NO}$ (with dilute acid)
$\text{Mn}^{2+}$ (acid), $\text{MnO}_2$ (base)
$\text{H}_2\text{O}$
$\text{Cr}^{3+}$
$\text{I}^-$
$\text{Sn}^{2+}$
$\text{Fe}^{2+}$
$\text{F}^-$ / $\text{Cl}^-$

### Common Reducing Agents

hydrogen peroxide	$\text{H}_2\text{O}_2$
sulfite	$\text{SO}_3^{2-}$
dihydrogen	$\text{H}_2$
metal	$\text{M}^0$
iodide	$\text{I}^-$
thiosulfate	$\text{S}_2\text{O}_3^{2-}$

### Oxidized to

$\text{O}_2$
$\text{SO}_4^{2-}$
$\text{H}^+$
$\text{M}^+$
$\text{I}_2$
$\text{SO}_4^{2-}$ , $\text{S}_2\text{O}_6^{2-}$ with $\text{I}_2$ ; $\text{S}$ and $\text{SO}_2(\text{g})$ with $\text{H}^+$

Other Oxidizing Agents:  $\text{Br}_2 \rightarrow \text{Br}^-$ ;  $\text{O}_2 \rightarrow \text{H}_2\text{O}$  or  $\text{OH}^-$

Other Reducing Agents:  $\text{Zn} \rightarrow \text{Zn}^{2+}$ ;  $\text{Al} \rightarrow \text{Al}^{3+}$ ;  $\text{H}_2\text{C}_2\text{O}_4$  (oxalic acid)  $\rightarrow \text{CO}_2$

Reactions with dioxygen usually produce oxides (binary compounds of oxygen).

$\text{Cu}$  (or other inactive metal) + acid  $\rightarrow \text{Cu}^{2+}$  + funny reduction products, but not  $\text{H}_2$

Must show the element in the equation is changing oxidation number.

Manganese:  $+7 \rightarrow +2$  in acid solution;  $+7 \rightarrow +4$  in basic solution.

Chromium: dichromate to  $\text{Cr}^{3+}$  in acid solution; chromate to  $\text{Cr}(\text{OH})_3$  in basic solution.

Oxygen: hydrogen peroxide can act as an oxidizing agent (reduced to water) and a reducing agent (oxidized to oxygen gas).

Nitrogen: nitrate ion is an oxidizing agent only in acid solution. The reduction product is  $\text{NO}$ .

Sulfur: sulfate ion is an oxidizing agent only in acid solution. The reduction product is  $\text{SO}_2$ .

Will go to  $\text{H}_2\text{S}$  with hot, concentrated acid.

1. Hydrogen peroxide is added to an acidified solution of potassium dichromate.
2. Sulfur dioxide gas is bubbled through an acidified solution of potassium permanganate.
3. A solution containing tin(II) ions is added to an acidified solution of potassium dichromate.
4. A dilute solution of sulfuric acid is electrolyzed between platinum electrodes.
5. Potassium permanganate solution is added to a solution of oxalic acid, acidified with a few drops of sulfuric acid.
6. Powdered iron is added to solution of iron(III) sulfate.
7. Copper(II) sulfide is oxidized by dilute nitric acid.
8. A solution of formic acid is oxidized by an acidified solution of potassium dichromate.
9. A solution of copper(II) sulfate is electrolyzed using inert electrodes.
10. Concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.
11. Chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.
12. A solution of potassium permanganate is mixed with an alkaline solution of sodium sulfite.
13. Concentrated hydrochloric acid added to solid manganese dioxide and heated.
14. Solid sodium dichromate is added to an acidified solution of sodium iodide.
15. Solutions of potassium iodate are mixed in acid solution.
16. Hydrogen peroxide is added to an acidified solution of sodium bromide.
17. A 0.1 M potassium permanganate solution is acidified with 3 M sulfuric acid and mixed with 0.1 M sodium bromide solution.
18. The cathode reaction in the electrolysis of sodium chloride solution when platinum electrodes are used.
19. Iron(III) ions are reduced by iodide ions.
20. Potassium permanganate solution is added to concentrated hydrochloric acid.
21. Potassium dichromate solution is added to an acidified solution of sodium sulfite.
22. Solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.
23. A solution of tin(II) sulfate is added to a solution of iron(III) sulfate.
24. Manganese(IV) oxide is added to warm, concentrated hydrobromic acid.
25. Solid iron(III) oxide is heated in excess carbon monoxide.
26. Hydrogen peroxide solution is added to acidified potassium iodide solution.
27. A solution of tin(II) chloride is added to a solution of potassium sulfide.
28. An acidified solution of sodium permanganate is added to a solution of sodium sulfite.
29. Dilute hydrochloric acid is added to a solution of potassium sulfite.
30. A piece of iron is added to a solution of iron(III) sulfate.
31. Solid silver is added to a dilute nitric acid (6M) solution.
32. Hydrogen peroxide solution is added to a solution of iron(II) sulfate.
33. A solution of potassium iodide is added to an acidified solution of potassium dichromate.
34. A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.
35. A piece of solid bismuth is heated strongly in oxygen.

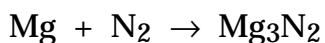
36. A solution of potassium iodide is electrolyzed.
37. Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
38. Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
39. A solution of iron(II) nitrate is exposed to air for an extended period of time.
40. Chlorine gas is bubbled into a solution of sodium bromide.
41. Solutions of potassium permanganate and sodium oxalate are mixed.

## VII. SINGLE REPLACEMENT

1. Calcium metal is added to a dilute solution of hydrochloric acid.
2. Liquid bromine is added to a solution of potassium iodide.
3. Pellets of lead are dropped into hot sulfuric acid.
4. Magnesium turnings are added to a solution of iron(III) chloride.
5. Chlorine gas is bubbled into a solution of sodium bromide.
6. Solid zinc strips are added to a solution of copper sulfate.
7. Solid copper is added to a dilute nitric acid solution.
8. Lead foil is immersed in silver nitrate solution.
9. Hydrogen gas is passed over hot iron(III) oxide.
10. Chlorine gas is bubbled through dilute sodium hydroxide.
11. Magnesium metal is added to dilute nitric acid, giving as one of the products a compound in which the oxidation number of nitrogen is -3.
12. Aluminum metal is added to a solution of copper(II) chloride.
13. Hydrogen gas is passed over hot copper(II) oxide.
14. Solid zinc sulfide is heated in an excess of oxygen.
15. Metallic copper is heated in an excess of oxygen.
16. Chlorine gas is bubbled into cold dilute sodium hydroxide.
17. Small chunks of solid sodium are added to water.
18. Sodium is added to water.
19. Chlorine gas is bubbled into a solution of potassium iodide.
20. Solid calcium is added to warm water.
21. A strip of magnesium is added to a solution of silver nitrate.
22. A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.
23. A strip of copper metal is added to a concentrated solution of sulfuric acid.
24. Solid copper(II) sulfide heated in oxygen gas.
25. A piece of aluminum metal is added to a solution of silver nitrate.
26. A strip of copper is immersed in dilute nitric acid.
27. Concentrated hydrochloric acid is added to solid manganese(II) sulfide.
28. A bar of zinc metal is immersed in a solution of copper(II) sulfate.
29. A piece of nickel metal is immersed in a solution of copper(II) sulfate.

## VIII. ADDITION/COMBINATION

metallic element + nonmetallic element → ionic compound



1. Solid calcium oxide is exposed to a stream of carbon dioxide gas.
2. Sodium hydrogen carbonate is dissolved in water.
3. Ammonia gas and carbon dioxide gas are bubbled into water.
4. Magnesium metal is burned in nitrogen gas.
5. Sulfur dioxide gas is passed over solid calcium oxide.
6. A mixture of solid calcium oxide and solid tetraphosphorus decaoxide is heated.
7. Powdered magnesium oxide is added to a container of carbon dioxide gas.
8. A piece of lithium metal is dropped into a container of nitrogen gas.
9. The gases boron trifluoride and ammonia are mixed.
10. Sulfur trioxide gas is added to excess water.
11. Samples of boron trichloride gas and ammonia are mixed.

12. Calcium metal heated in nitrogen gas.
13. Solid calcium oxide heated with sulfur trioxide gas.
14. Excess chlorine gas is passed over hot iron filings.

### **IX. DECOMPOSITION**

metallic carbonates → metallic oxides + carbon dioxide

metallic chlorates → metallic chlorides + oxygen gas

metallic hydroxides → metallic oxides + water (reverse of basic anhydrides)

acids → nonmetallic oxide + water (reverse of acid anhydrides)

1. A solution of hydrogen peroxide is decomposed catalytically.
2. Solid ammonium carbonate is heated.
3. Solid magnesium carbonate is heated.
4. Solid potassium chlorate is heated in the presence of manganese dioxide catalyst.
5. A solution of hydrogen peroxide is heated.
6. Solid calcium carbonate is strongly heated.