

WRITING AP* NET IONIC EQUATIONS

AP equation sets are found in the free-response section of the AP test. You are given eight equations and you must choose to answer five of these.** The equations are of mixed types. The section is worth 15 points and is 15 % of the free response grade. Free response is 55% of the total AP test grade.

All AP equations "work". In each case, a reaction will occur. These equations need to be written in net ionic form. All spectator ions must be left out and all ions must be written in ionic form. All molecular substances and nonsoluble compounds must be written together (not ionized!). Weak electrolytes, such as acetic acid, are not ionized. Solids and pure liquids are written together, also. A saturated solution is written in ionic form while a suspension is written together. AP equations do not need to be balanced. Don't waste your time on balancing!

Each equation is worth a total of 3 points. One point is given for the correct reactants and two points for all correct products. If a reaction has three products, one point is given for two correct products and two points for all correct products. Leaving in the spectator ions will result in a one point deduction on the equation set (not 1 point per problem).

The best way to prepare for the equation section of the AP test is to practice lots of equations. The equation sets are similar and some equations show up year after year. When you are reading an equation, first try to classify it by type. If it says anything about acidic or basic solution, it is redox. If you are totally stuck, look up the compounds in the index of your book or other reference books and try to find information that will help you with the equation. All reactions do not fit neatly into the five types of reactions that you learned in Chemistry I. Save the reactions that you write and practice them again before the AP test in May.

Kristen Henry Jones 01/28/99

**** There was a format change in 2007. Now students are given 3 equations and only 3 equations, each worth 5 points. They must write the net ionic equation (3 points total: 1 point for *set of* reactants and 2 points for products), balance the net ionic equation (the 4th point), and answer a descriptive question about the reaction (the 5th and final point). The methods presented in this document still hold true, but be sure and require students to balance the equations by mass and charge even though they are not balanced on the key!**

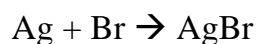
(1) AP[®] is a registered trademark of the College Board. The College Board was not involved in the production of and does not endorse this product. (2) Test Questions are Copyright © 1962-2008 by College Entrance Examination Board, Princeton, NJ. All rights reserved. For face-to-face teaching purposes, classroom teachers are permitted to reproduce the questions. Web or Mass distribution prohibited.

Double Replacement (metathesis)

Two compounds react to form two new compounds. No changes in oxidation numbers occur. All double replacement reactions must have a "driving force" that removes a pair of ions from solution.

Formation of a precipitate: A precipitate is an insoluble substance formed by the reaction of two aqueous substances. Two ions bond together so strongly that water can not pull them apart. You must know your solubility rules to write these net ionic equations (see next page)

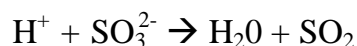
Ex. Solutions of silver nitrate and lithium bromide are mixed.



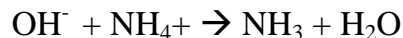
Formation of a gas: Gases may form directly in a double replacement reaction or can form from the decomposition of a product such as H_2CO_3 or H_2SO_3 .

Common gasses: CO_2 , SO_2 , SO_3 , H_2S , NO_2 , NH_3 , O_2 , H_2

Ex. Excess hydrochloric acid solution is added to a solution of potassium sulfite.



Ex. A solution of sodium hydroxide is added to a solution of ammonium chloride.



Formation of a molecular substance: When a molecular substance such as water or acetic acid is formed, ions are removed from solution and the reaction "works".

Ex. Dilute solutions of lithium hydroxide and hydrobromic acid are mixed.



Ex. Gaseous hydrofluoric acid reacts with solid silicon dioxide.



Solubility Rules

These are strong electrolytes (100% ionized) and written as ions

1. Strong Acids: HCl, HBr, HI, H₂SO₄, HNO₃, HClO₄
2. Strong Bases: Hydroxides of group IA and IIA (Ba, Sr, Ca are marginal Be and Mg are WEAK)
3. Soluble Salts (see table): (ionic compounds: metal/nonmetal)

ALWAYS SOUBLE IF IN A COMPOUND	EXCEPT WITH
NO ₃ ⁻ , Group IA, NH ₄ ⁺ , C ₂ H ₃ O ₂ ⁻ , ClO ₄ ⁻ , ClO ₃ ⁻	No Exceptions
Cl ⁻ , Br ⁻ , I ⁻	Pb, Ag, Hg ₂ ²⁺
SO ₄ ²⁻	Pb, Ag, Hg ₂ ²⁺ Ca, Sr, Ba

If it does not fit one of the three rules above, assume it is INSOLUBLE or a WEAK ELECTROLYTE (and written together). This won't always be correct, but will cover most of the situations.

Also, GASES, PURE LIQUIDS, and SOLIDS are non-electrolytes.

Remember H₂CO₃ decomposes into H₂O_(l) and CO_{2(g)}

Remember NH₄OH decomposes into H₂O_(l) and NH_{3(g)}

Remember H₂SO₃ decomposes into H₂O and SO₂

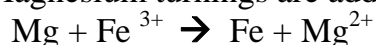
Single Replacement

Reaction where one element displaces another in a compound. One element is oxidized and another is reduced.



Active metals replace less active metals or hydrogen from their compounds in aqueous solution. Use an activity series or a reduction potential table to determine activity. The more easily oxidized metal replaces the less easily oxidized metal. The metal with the *most negative* reduction potential will be the *most active*.

Ex. Magnesium turnings are added to a solution of iron(III) chloride.

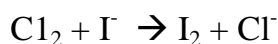


Ex. Sodium is added to water.



Active nonmetals replace less active nonmetals from their compounds in aqueous solution. Each halogen will displace less electronegative (heavier) halogens from their binary salts.

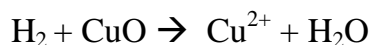
Ex. Chlorine gas is bubbled into a solution of potassium iodide.



Tricky redox reactions that appear to be ordinary single replacement reactions:

- Hydrogen reacts with a hot metallic oxide to produce the elemental metal and water.

Ex. Hydrogen gas is passed over hot copper(II) oxide.



- A metal sulfide reacts with oxygen to produce the metallic oxide and sulfur dioxide.
- Chlorine gas reacts with dilute sodium hydroxide to produce sodium hypochlorite, sodium chloride and water.

- Copper reacts with concentrated sulfuric acid to produce copper(II) sulfate, sulfur dioxide, and water.
- Copper reacts with dilute nitric acid to produce copper(II) nitrate, nitrogen monoxide and water.
- Copper reacts with concentrated nitric acid to produce copper(II) nitrate, nitrogen dioxide and water

Anhydrides

- Anhydride means "without water"
- Water is a reactant in each of these equations.

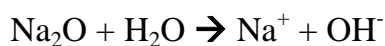
Nonmetallic oxides (acidic anhydrides) plus water yield acids.

Ex. Carbon dioxide is bubbled into water.



Metallic oxides (basic anhydrides) plus water yield bases.

Ex. Solid sodium oxide is added to water.



Metallic hydrides (ionic hydrides) plus water yield metallic hydroxides and hydrogen gas.

Ex. Solid sodium hydride is added to water.



Phosphorus halides react with water to produce an acid of phosphorus (phosphorous acid or phosphoric acid) and a hydrohalic acid. The oxidation number of the phosphorus remains the same in both compounds. Phosphorus oxytrichloride reacts with water to make the same products.

Ex. Phosphorus tribromide is added to water.



Group I&II nitrides react with water to produce the metallic hydroxide and ammonia.

OXIDATION-REDUCTION REACTIONS

Redox reactions involve the transfer of electrons. The oxidation numbers of at least two elements must change. Single replacement, some combination and some decomposition reactions are redox reactions.

To predict the products of a redox reaction, look at the reagents given to see if there is both an oxidizing agent and a reducing agent. When a problem mentions an acidic or basic solution, it is probably redox.

Common oxidizing agents

MnO_4^- in acidic solution
 MnO_2 in acidic solution
 MnO_4^- in neutral or basic solution
 $\text{Cr}_2\text{O}_7^{2-}$ in acidic solution
 HNO_3 , concentrated
 HNO_3 , dilute
 H_2SO_4 , hot, concentrated
metal-ic ions
free halogens
 Na_2O_2
 HClO_4
 H_2O_2

Products formed

Mn^{2+}
 Mn^{2+}
 $\text{MnO}_2(\text{s})$
 Cr^{3+}
 NO_2
 NO
 SO_2
metal-ous ions
halide ions
 NaOH
 Cl^-
 H_2O

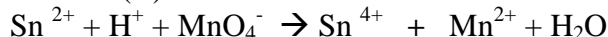
Common reducing agents

halide ions
free metals
sulfite ions or SO_2
nitrite ions
free halogens, dilute basic solution
free halogens, conc. basic solution
metal-ous ions
 H_2O_2
 $\text{C}_2\text{O}_4^{2-}$

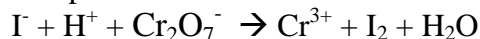
Products formed

free halogen
metal ions
sulfate ions
nitrate ions
hypohalite ions
halate ions
metal-ic ions
 O_2
 CO_2

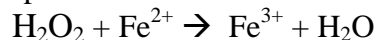
Ex. A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.



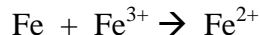
Ex. A solution of potassium iodide is added to an acidified solution of potassium dichromate.



Ex. Hydrogen peroxide solution is added to a solution of iron(II) sulfate.



Ex. A piece of iron is added to a solution of iron(III) sulfate.



COMPLEX ION REACTIONS

Complex ion- the combination of a central metal ion and its ligands

Ligand- group bonded to a metal ion

Coordination compound- a neutral compound containing complex ions $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

(NH_3 is the ligand, $[\text{Co}(\text{NH}_3)_6]^{3+}$ is the complex ion)

Common complex ions formed in AP equations:

Complex ion Name	Formed from:
$[\text{Al}(\text{OH})_4]^-$ tetrahydroxoaluminate ion	(Al or $\text{Al}(\text{OH})_3$ or $\text{Al}^{3+} + \text{OH}^-$)
$[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ hexaquaaluminum ion	(Al^{3+} in H_2O)
$[\text{Ag}(\text{NH}_3)_2]^+$ dimminesilver(I) ion	($\text{Ag}^+ + \text{NH}_3$)
$[\text{Zn}(\text{OH})_4]^{2-}$ tetrahydroxozincate ion	($\text{Zn}(\text{OH})_2 + \text{OH}^-$)
$[\text{Zn}(\text{NH}_3)_4]^{2+}$ tetramminezinc ion	($\text{Zn}^{2+} + \text{NH}_3$)
$[\text{Cu}(\text{NH}_3)_4]^{2+}$ tetramminecopper(II) ion	($\text{Cu}^{+2} + \text{NH}_3$)
$[\text{Cd}(\text{NH}_3)_4]^{2+}$ tetramminecadmium(II) ion	($\text{Cd}^{2+} + \text{NH}_3$)
$[\text{FeSCN}]^{+2}$ thiocyanoiron(III) ion	($\text{Fe}^{+3} + \text{SCN}^-$)
$[\text{Ag}(\text{CN})_2]^-$ dicyanoargentate (I) ion	($\text{Ag}^+ + \text{CN}^-$)

Adding an acid to a complex ion will break it up. If HCl is added to a silver complex, $\text{AgCl}(s)$ is formed. If an acid is added to an ammonia complex, NH_4^+ is formed.

Kristen Henry Jones 01/28/99

DECOMPOSITION REACTIONS

Reactions where a compound breaks down into two or more elements or compounds. Heat, electrolysis, or a catalyst is usually necessary.

A compound may break down to produce two elements.

Ex. Molten sodium chloride is electrolyzed.



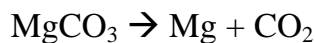
A compound may break down to produce an element and a compound.

Ex. A solution of hydrogen peroxide is decomposed catalytically.



A compound may break down to produce two compounds.

Ex. Solid magnesium carbonate is heated.



Metallic carbonates break down to yield metallic oxides and carbon dioxide,

Metallic chlorates break down to yield metallic chlorides and oxygen.

Hydrogen peroxide decomposes into water and oxygen.

Ammonium carbonate decomposes into ammonia, water and carbon dioxide.

Sulfurous acid decomposes into water and sulfur dioxide.

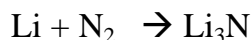
Carbonic acid decomposes into water and carbon dioxide.

ADDITION REACTIONS

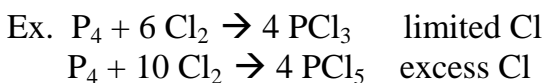
Two or more elements or compounds combine to form a single product.

A group IA or IIA metal may combine with a nonmetal to make a salt.

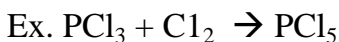
Ex. A piece of lithium metal is dropped into a container of nitrogen gas.



Two nonmetals may combine to form a molecular compound. The oxidation number of the less electronegative element is often variable depending upon conditions. Generally, a higher oxidation state of one nonmetal is obtained when reacting with an excess of the other nonmetal.



When an element combines with a compound, you can usually sum up all of the elements on the product side.

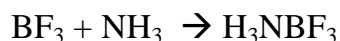


Two compounds combine to form a single product.

Ex. Sulfur dioxide gas is passed over solid calcium oxide.



Ex. The gases boron trifluoride and ammonia are mixed.



A metallic oxide plus carbon dioxide yields a metallic carbonate. (Carbon keeps the same oxidation state)

A metallic oxide plus sulfur dioxide yields a metallic sulfite. (Sulfur keeps the same oxidation state)

A metallic oxide plus water yields a metallic hydroxide.

A nonmetallic oxide plus water yields an acid.

ACID-BASE NEUTRALIZATION REACTIONS

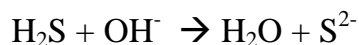
Acids react with bases to produce salts and water. One mole of hydrogen ions react with one mole of hydroxide ions to produce one mole of water. Watch out for information about quantities of each reactant! Remember which acids are strong (ionize completely) and which are weak (write as molecule).

Sulfuric acid (strong acid) can be written as H^+ and SO_4^{2-} or as H^+ and HSO_4^- .

Ex. A solution of sulfuric acid is added to a solution of barium hydroxide until the same number of moles of each compound as been added.

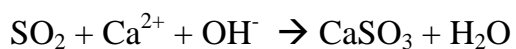


Ex. Hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.



Watch out for substances that react with water before reacting with an acid or a base. These are two-step reactions.

Ex. Sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.



COMBUSTION REACTIONS

Elements or compounds combine with oxygen.

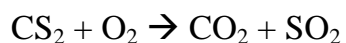
Hydrocarbons or alcohols combine with oxygen to form carbon dioxide and water.

Ammonia combines with limited oxygen to produce NO and water and with excess oxygen to produce NO₂ and water.

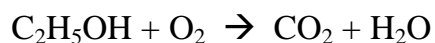
Nonmetallic hydrides combine with oxygen to form oxides and water.

Nonmetallic sulfides combine with oxygen to form oxides and sulfur dioxide.

Ex. Carbon disulfide vapor is burned in excess oxygen.



Ex. Ethanol is burned completely in air.



AP CHEMISTRY EQUATIONS BY TYPE

Double Replacement

1. Hydrogen sulfide is bubbled through a solution of silver nitrate.
2. An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.
3. Solutions of sodium iodide and lead nitrate are mixed.
4. A solution of ammonia is added to a solution of ferric chloride.
5. Solutions of silver nitrate and sodium chromate are mixed.
6. Excess silver acetate is added to a solution of trisodium phosphate.
7. Manganese(II) nitrate solution is mixed with sodium hydroxide solution.
8. A saturated solution of calcium hydroxide is added to a solution of magnesium chloride.
9. Hydrogen sulfide gas is added to a solution of cadmium nitrate.
10. Dilute sulfuric acid is added to a solution of barium acetate.
11. A precipitate is formed when solutions of trisodium phosphate and calcium chloride are mixed.
12. A solution of copper(II) sulfate is added to a solution of barium hydroxide.
13. Equal volumes of dilute equimolar solutions of sodium carbonate and hydrochloric acid are mixed.
14. Solid barium peroxide is added to cold dilute sulfuric acid.
15. Excess hydrochloric acid solution is added to a solution of potassium sulfite.
16. Dilute sulfuric acid is added to a solution of barium chloride.
17. A solution of sodium hydroxide is added to a solution of ammonium chloride.
18. Dilute hydrochloric acid is added to a solution of potassium carbonate.
19. Gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.
20. A solution of sodium sulfide is added to a solution of zinc nitrate.
21. Concentrated hydrochloric acid is added to solid manganese(II) sulfide.
22. Solutions of tri-potassium phosphate and zinc nitrate are mixed.
23. Dilute acetic acid solution is added to solid magnesium carbonate.
24. Gaseous hydrofluoric acid reacts with solid silicon dioxide.
25. Equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.
26. Ammonium chloride crystals are added to a solution of sodium hydroxide.
27. Hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.
28. Solutions of silver nitrate and sodium chromate are mixed.
29. Solutions of sodium fluoride and dilute hydrochloric acid are mixed.
30. A saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.
31. A solution of ammonium sulfate is added to a potassium hydroxide solution.
32. A solution of ammonium sulfate is added to a saturated solution of barium hydroxide.
33. Dilute sulfuric acid is added to solid calcium fluoride.
34. Dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.
35. Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.
36. Dilute hydrochloric acid is added to a solution of potassium sulfite.
37. Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.
38. Excess concentrated sulfuric acid is added to solid calcium phosphate.
39. Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.
40. Solutions of zinc sulfate and sodium phosphate are mixed.
41. Solutions of silver nitrate and lithium bromide are mixed.

42. Solutions of manganese(II) sulfate and ammonium sulfide are mixed.
43. Excess hydrochloric acid solution is added to a solution of potassium sulfite.

Single Replacement

1. A piece of aluminum metal is added to a solution of silver nitrate.
2. Aluminum metal is added to a solution of copper(II) chloride.
3. Hydrogen gas is passed over hot copper(II) oxide.
4. Small chunks of solid sodium are added to water.
5. Calcium metal is added to a dilute solution of hydrochloric acid.
6. Magnesium turnings are added to a solution of iron(III) chloride.
7. Chlorine gas is bubbled into a solution of sodium bromide.
8. A strip of magnesium is added to a solution of silver nitrate.
9. Solid calcium is added to warm water.
10. Liquid bromine is added to a solution of potassium iodide.
11. Chlorine gas is bubbled into a solution of potassium iodide.
12. Lead foil is immersed in silver nitrate solution.
13. Solid zinc strips are added to a solution of copper(II) sulfate.
14. Sodium metal is added to water.
15. A bar of zinc metal is immersed in a solution of copper(II) sulfate.
16. A small piece of sodium metal is added to distilled water.

Anhydrides

1. Excess water is added to solid calcium hydride.
2. Solid lithium hydride is added to water.
3. Liquid phosphorus trichloride is poured into a large excess of water.
4. Solid sodium carbide is added to an excess of water.
5. Solid magnesium nitride is added to excess deuterium oxide.
6. Water is added to a sample of pure phosphorus tribromide.
7. Water is added to a sample of pure sodium hydride.
8. Dinitrogen trioxide gas is bubbled into water.
9. Solid phosphorus pentachloride is added to excess water.
10. Solid dinitrogen pentoxide is added to water.
11. Sulfur trioxide gas is added to excess water.
12. Solid sodium oxide is added to water.
13. Phosphorus(V) oxytrichloride is added to water.
14. Water is added to a sample of solid magnesium nitride.
15. Solid potassium oxide is added to water.
16. Solid sodium cyanide is added to water.
17. Trisodium phosphate crystals are added to water.
18. Solid lithium oxide is added to excess water.
19. Solid barium oxide is added to distilled water.
20. Solid calcium hydride is added to distilled water.
21. Phosphorous(V) oxide powder is sprinkled over distilled water.

Combustion

1. Lithium metal is burned in air.
2. The hydrocarbon hexane is burned in excess oxygen.

3. Gaseous diborane, B_2H_6 , is burned in excess oxygen.
4. A piece of solid bismuth is heated strongly in oxygen.
5. Solid zinc sulfide is heated in an excess of oxygen.
6. Propanol is burned completely in air.
7. Excess oxygen gas is mixed with ammonia gas in the presence of platinum.
8. Gaseous silane, SiH_4 , is burned in oxygen.
9. Ethanol is completely burned in air.
10. Solid copper(II) sulfide is heated strongly in oxygen gas.
11. Ethanol is burned in oxygen.
12. Carbon disulfide vapor is burned in excess oxygen.

Redox

1. Iron(III) ions are reduced by iodide ions.
2. Potassium permanganate solution is added to concentrated hydrochloric acid.
3. Magnesium metal is added to dilute nitric acid, giving as one of the products a compound in which the oxidation number for nitrogen is -3.
4. A solution of potassium iodide is electrolyzed.
5. Potassium dichromate solution is added to an acidified solution of sodium sulfite.
6. Solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.
7. A solution of tin(II) sulfate is added to a solution of iron(III) sulfate.
8. Metallic copper is heated with concentrated sulfuric acid.
9. Manganese(IV) oxide is added to warm, concentrated hydrobromic acid.
10. Chlorine gas is bubbled into cold dilute sodium hydroxide.
11. Solid iron(III) oxide is heated in excess carbon monoxide.
12. Hydrogen peroxide solution is added to acidified potassium iodide solution.
13. Hydrogen peroxide is added to an acidified solution of potassium dichromate.
14. Sulfur dioxide gas is bubbled through an acidified solution of potassium permanganate.
15. A solution containing tin(II) ions is added to an acidified solution of potassium dichromate.
16. Solid silver sulfide is warmed with dilute nitric acid.
17. A dilute solution of sulfuric acid is electrolyzed between platinum electrodes.
18. Pellets of lead are dropped into hot sulfuric acid.
19. Potassium permanganate solution is added to a solution of oxalic acid, $H_2C_2O_4$, acidified with a few drops of sulfuric acid.
20. Powdered iron is added to a solution of iron(III) sulfate.
21. A concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated.
22. A strip of copper metal is added to a concentrated solution of sulfuric acid.
23. Copper(II) sulfide is oxidized by dilute nitric acid.
24. A solution of copper(II) sulfate is electrolyzed using inert electrodes.
25. A solution of potassium iodide is added to an acidified solution of potassium dichromate.
26. Hydrogen peroxide solution is added to a solution of iron(II) sulfate.
27. Solid silver is added to a dilute nitric acid (6M) solution.
28. A solution of formic acid, $HCOOH$, is oxidized by an acidified solution of potassium dichromate.
29. A piece of iron is added to a solution of iron(III) sulfate.
30. An acidified solution of potassium permanganate is added to a solution of sodium sulfite.

31. A solution of tin(II) chloride is added to a solution of iron(III) sulfate.
32. Concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.
33. A strip of copper is immersed in dilute nitric acid.
34. Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
35. Solid copper is added to a dilute nitric acid solution.
36. Chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.
37. A solution of potassium permanganate is mixed with an alkaline solution of sodium sulfite.
38. Solid sodium dichromate is added to an acidified solution of sodium iodide.
39. Hydrogen gas is passed over hot iron(III) oxide.
40. Solutions of potassium iodide and potassium iodate are mixed in acid solution.
41. Hydrogen peroxide is added to an acidified solution of sodium bromide.
42. Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
44. A solution of iron(II) nitrate is exposed to air for an extended period of time.
45. A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.
46. A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.
47. A concentrated solution of hydrochloric acid is added to solid potassium permanganate.
48. A solution of potassium dichromate is added to an acidified solution of iron(II) chloride.

Acid-Base Neutralizations

1. Solutions of ammonia and hydrofluoric acid are mixed.
2. Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.
3. 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. of
4. 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. the
5. Dilute nitric acid is added to crystals of pure calcium oxide.
6. Equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed.
7. A solution of ammonia is added to a dilute solution of acetic acid.
8. Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
9. Sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.
10. 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 the calcium salt.
11. Equal volumes of 0.1M hydrochloric acid and 0.1M sodium monohydrogen phosphate are mixed.
12. Hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.
13. Ammonia gas and carbon dioxide gas are bubbled into water.
14. Carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.
15. Acetic acid solution is added to a solution of sodium hydrogen carbonate.

16. Excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.
17. Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide.

Complex Ions

1. Concentrated (15M) ammonia solution is added in excess to a solution of copper(II) nitrate.

2. An excess of nitric acid solution is added to a solution of tetraamminecopper(II) sulfate.
3. Dilute hydrochloric acid is added to a solution of diamminesilver(I) nitrate.
4. Solid aluminum nitrate is dissolved in water.
5. A suspension of copper(II) hydroxide is treated with an excess of ammonia water.
6. A solution of diamminesilver(I) chloride is treated with dilute nitric acid.
7. An excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.
8. Excess dilute nitric acid is added to a solution containing the tetraamminecadmium(II) ion.
9. An excess of ammonia is bubbled through a solution saturated with silver chloride.
10. Solid aluminum oxide is added to a solution of sodium hydroxide.
11. A concentrated solution of ammonia is added to a solution of zinc iodide.
12. An excess of sodium hydroxide solution is added to a solution of aluminum chloride.
13. A concentrated solution of ammonia is added to a solution of copper(II) chloride.
14. Excess concentrated sodium hydroxide solution is added to solid aluminum hydroxide.
15. Excess concentrated ammonia solution is added to a suspension of silver chloride.
16. Pellets of aluminum metal are added to a solution containing an excess of sodium hydroxide.
17. A suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.
18. Silver chloride is dissolved in excess ammonia solution.
19. Sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.
20. A drop of potassium thiocyanate is added to a solution of iron(III) chloride.
21. A concentrated solution of ammonia is added to a suspension of zinc hydroxide.
22. Excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.
23. A solution of ammonium thiocyanate is added to a solution of iron(III) chloride.
24. Excess sodium cyanide is added to a solution of silver nitrate.

Addition

1. The gases boron trifluoride and ammonia are mixed.
2. A mixture of solid calcium oxide and solid tetraphosphorus decaoxide is heated.
3. Solid calcium oxide is exposed to a stream of carbon dioxide gas.
4. Solid calcium oxide is heated in the presence of sulfur trioxide gas.
5. Calcium metal is heated strongly in nitrogen gas.
6. Excess chlorine gas is passed over hot iron filings.
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. Magnesium metal is burned in nitrogen gas.
10. Sulfur dioxide gas is passed over solid calcium oxide.
11. Samples of boron trichloride gas and ammonia gas are mixed.

Decomposition

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