DOUBLE REPLACEMENT

1. Hydrogen sulfide is bubbled through a solution of silver nitrate.
   \[ \text{H}_2\text{S} + \text{Ag}^{+} \rightarrow \text{Ag}_2\text{S} + \text{H}^{+} \]

2. An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.
   \[ \text{OH}^- + \text{Mg}^{2+} \rightarrow \text{Mg(OH)}_2 \]

3. Solutions of sodium iodide and lead nitrate are mixed.
   \[ \Gamma^- + \text{Pb}^{2+} \rightarrow \text{Pbl}_2 \]

4. A solution of ammonia is added to a solution of ferric chloride.
   \[ \text{NH}_3 + \text{H}_2\text{O} + \text{Fe}^{3+} \rightarrow \text{NH}_4^+ + \text{Fe(OH)}_3 \]

5. Solutions of silver nitrate and sodium chromate are mixed.
   \[ \text{Ag}^+ + \text{CrO}_4^{2-} \rightarrow \text{Ag}_2\text{CrO}_4 \]

6. Excess silver acetate is added to a solution of trisodium phosphate.
   \[ \text{Ag}^+ + \text{PO}_4^{3-} \rightarrow \text{Ag}_3\text{PO}_4 \]

7. Manganese(II) nitrate solution is mixed with sodium hydroxide solution.
   \[ \text{Mn}^{2+} + \text{OH}^- \rightarrow \text{Mn(OH)}_2 \]

8. A saturated solution of calcium hydroxide is added to a solution of magnesium chloride.
   \[ \text{Mg}^{2+} + \text{OH}^- \rightarrow \text{Mg(OH)}_2 \]

9. Hydrogen sulfide gas is added to a solution of cadmium nitrate.
   \[ \text{H}_2\text{S} + \text{Cd}^{2+} \rightarrow \text{CdS} + \text{H}^+ \]

10. Dilute sulfuric acid is added to a solution of barium acetate.
    \[ \text{H}^+ + \text{SO}_4^{2-} + \text{Ba}^{2+} + \text{C}_2\text{H}_3\text{O}_2^- \rightarrow \text{BaSO}_4 + \text{HC}_2\text{H}_3\text{O}_2 \]

11. A precipitate is formed when solutions of trisodium phosphate and calcium chloride are mixed.
    \[ \text{PO}_4^{3-} + \text{Ca}^{2+} \rightarrow \text{Ca}_3(\text{PO}_4)_2 \]

12. A solution of copper(II) sulfate is added to a solution of barium hydroxide.
    \[ \text{Cu}^{2+} + \text{SO}_4^{2-} + \text{Ba}^{2+} + \text{OH}^- \rightarrow \text{Cu(OH)}_2 + \text{BaSO}_4 \]

13. Equal volumes of dilute equimolar solutions of sodium carbonate and hydrochloric acid are mixed.
    \[ \text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^- \]

14. Solid barium peroxide is added to cold dilute sulfuric acid.
    \[ \text{BaO}_2 + \text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4 + \text{H}_2\text{O} \]

15. Excess hydrochloric acid solution is added to a solution of potassium sulfite.
    \[ \text{H}^+ + \text{SO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{SO}_2 \]

16. Dilute sulfuric acid is added to a solution of barium chloride.
    \[ \text{SO}_4^{2-} + \text{Ba}^{2+} \rightarrow \text{BaSO}_4 \]

17. A solution of sodium hydroxide is added to a solution of ammonium chloride.
    \[ \text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O} \]

18. Dilute hydrochloric acid is added to a solution of potassium carbonate.
    \[ \text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2 \]

19. Gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.
    \[ \text{H}_2\text{S} + \text{Ni}^{2+} \rightarrow \text{NiS} + \text{H}^+ \]

20. A solution of sodium sulfide is added to a solution of zinc nitrate.
\[ S^{2-} + \text{Zn}^{2+} \rightarrow \text{ZnS} \]

21. Concentrated hydrochloric acid is added to solid manganese(II) sulfide.
   \[ \text{H}^+ + \text{MnS} \rightarrow \text{H}_2\text{S} + \text{Mn}^{2+} \]

22. Solutions of tri-potassium phosphate and zinc nitrate are mixed.
   \[ \text{PO}_4^{3-} + \text{Zn}^{2+} \rightarrow \text{Zn}_3(\text{PO}_4)_2 \]

23. Dilute acetic acid solution is added to solid magnesium carbonate.
   \[ \text{HC}_2\text{H}_3\text{O}_2 + \text{MgCO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{Mg}^{2+} + \text{C}_2\text{H}_3\text{O}_2^- \]

24. Gaseous hydrofluoric acid reacts with solid silicon dioxide.
   \[ \text{HF} + \text{SiO}_2 \rightarrow \text{H}_2\text{O} + \text{SiF}_4 \]

25. Equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.
   \[ \text{PO}_4^{3-} + \text{H}^+ \rightarrow \text{HPO}_4^{2-} \]

26. Ammonium chloride crystals are added to a solution of sodium hydroxide.
   \[ \text{NH}_4\text{Cl} + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O} + \text{Cl}^- \]

27. Hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.
   \[ \text{H}_2\text{S} + \text{Pb}^{2+} \rightarrow \text{PbS} + \text{H}^+ \]

28. Solutions of silver nitrate and sodium chromate are mixed.
   \[ \text{Ag}^+ + \text{CrO}_4^{2-} \rightarrow \text{Ag}_2\text{CrO}_4 \]

29. Solutions of sodium fluoride and dilute hydrochloric acid are mixed.
   \[ \text{F}^- + \text{H}^+ \rightarrow \text{HF} \]

30. A saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.
    \[ \text{Ba}^{2+} + \text{OH}^- + \text{Fe}^{3+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4 + \text{Fe(OH)}_3 \]

31. A solution of ammonium sulfate is added to a potassium hydroxide solution.
    \[ \text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O} \]

32. A solution of ammonium sulfate is added to a saturated solution of barium hydroxide.
    \[ \text{NH}_4^+ + \text{SO}_4^{2-} + \text{Ba}^{2+} + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O} + \text{BaSO}_4 \]

33. Dilute sulfuric acid is added to solid calcium fluoride.
    \[ \text{H}^+ + \text{SO}_4^{2-} + \text{CaF}_2 \rightarrow \text{CaSO}_4 + \text{HF} \]

34. Dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.
    \[ \text{Cl}^- + \text{Hg}^{2+} \rightarrow \text{HgCl}_2 \]

35. Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.
    \[ \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{O} + \text{CO}_2 \]

36. Dilute hydrochloric acid is added to a solution of potassium sulfite.
    \[ \text{H}^+ + \text{SO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{SO}_2 \]

37. Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.
    \[ \text{CO}_2 + \text{CaCO}_3 + \text{H}_2\text{O} \rightarrow \text{HCO}_3^- + \text{Ca}^{2+} \]

38. Excess concentrated sulfuric acid is added to solid calcium phosphate.
    \[ \text{H}_2\text{SO}_4 + \text{Ca}_3(\text{PO}_4)_2 \rightarrow \text{H}_3\text{PO}_4 + \text{CaSO}_4 \text{ (or Ca}^{2+} + \text{SO}_4^{2-}) \]

39. Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.
    \[ \text{H}_2\text{S} + \text{Hg}^{2+} \rightarrow \text{HgS} + \text{H}^+ \]

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**SingleReplacement**

1. A piece of aluminum metal is added to a solution of silver nitrate.

Kristen Henry Jones 2
Al + Ag⁺ → Al³⁺ + Ag
2. Aluminum metal is added to a solution of copper(II) chloride.
   Al + Cu²⁺ → Al³⁺ + Cu
3. Hydrogen gas is passed over hot copper(II) oxide.
   H₂ + CuO → H₂O + Cu
4. Small chunks of solid sodium are added to water.
   Na + H₂O → Na⁺ + OH⁻ + H₂
5. Calcium metal is added to a dilute solution of hydrochloric acid.
   Ca + H⁺ → Ca²⁺ + H₂
6. Magnesium turnings are added to a solution of iron(III) chloride.
   Mg + Fe³⁺ → Mg²⁺ + Fe
7. Chlorine gas is bubbled into a solution of sodium bromide.
   Cl₂ + Br⁻ → Cl⁻ + Br₂
8. A strip of magnesium is added to a solution of silver nitrate.
   Mg + Ag⁺ → Mg²⁺ + Ag
9. Solid calcium is added to warm water.
   Ca + H₂O → Ca²⁺ + OH⁻ + H₂
10. Liquid bromine is added to a solution of potassium iodide.
    Br₂ + I⁻ → Br⁻ + I₂
11. Chlorine gas is bubbled into a solution of potassium iodide.
    Cl₂ + I⁻ → Cl⁻ + I₂
12. Lead foil is immersed in silver nitrate solution.
    Pb + Ag⁺ → Pb²⁺ + Ag
13. Solid zinc strips are added to a solution of copper(II) sulfate.
    Zn + Cu²⁺ → Zn²⁺ + Cu
14. Sodium metal is added to water.
    Na + H₂O → Na⁺ + OH⁻ + H₂
15. A bar of zinc metal is immersed in a solution of copper(II) sulfate.
    Zn + Cu²⁺ → Zn²⁺ + Cu

Anhydrides
1. Excess water is added to solid calcium hydride.
   H₂O + CaH₂ → Ca²⁺ + OH⁻ or (Ca(OH)₂)+ H₂
2. Solid lithium hydride is added to water.
   LiH + H₂O → Li⁺ + OH⁻ + H₂
3. Liquid phosphorus trichloride is poured into a large excess of water.
   PCl₃ + H₂O → H₃PO₃ + H⁺ + Cl⁻
4. Solid sodium carbide is added to an excess of water.
   Na₄C + H₂O → C₂H₂ + Na⁺ + OH⁻
5. Solid magnesium nitride is added to excess deuterium oxide.
   Mg₃N₂ + D₂O → Mg(OD)₂⁻ + ND₃
6. Water is added to a sample of pure phosphorus tribromide.
   H₂O + PBr₃ → H₃PO₃ + H⁺ + Br⁻
7. Water is added to a sample of pure sodium hydride.
H₂O + NaH → Na⁺ + OH⁻ + H₂

8. Dinitrogen trioxide gas is bubbled into water.
N₂O₃ + H₂O → HNO₂

9. Solid phosphorus pentachloride is added to excess water.
PCl₅ + H₂O → H₃PO₄ + H⁺ + Cl⁻

10. Solid dinitrogen pentoxide is added to water.
N₂O₅ + H₂O → H⁺ + NO₃⁻

11. Sulfur trioxide gas is added to excess water.
SO₃ + H₂O → H⁺ + SO₄²⁻

12. Solid sodium oxide is added to water.
Na₂O + H₂O → Na⁺ + OH⁻

13. Phosphorus(V) oxytrichloride is added to water.
POCl₃ + H₂O → H₃PO₄ + H⁺ + Cl⁻

14. Water is added to a sample of solid magnesium nitride.
H₂O + Mg₃N₂ → Mg(OH)₂ + NH₃

15. Solid potassium oxide is added to water.
K₂O + H₂O → K⁺ + OH⁻

16. Solid sodium cyanide is added to water.
NaCN + H₂O → HCN + Na⁺ + OH⁻

17. Trisodium phosphate crystals are added to water.
Na₃PO₄ + H₂O → Na⁺ + OH⁻ + HPO₄²⁻ (or H₂PO₄⁻)

18. Solid lithium oxide is added to excess water.
Li₂O + H₂O → Li⁺ + OH⁻

19. Solid barium oxide is added to distilled water.
BaO + H₂O → Ba²⁺ + OH⁻

20. Solid calcium hydride is added to distilled water.
CaH₂⁺ H₂O → Ca²⁺ + OH⁻ or (Ca(OH)₂) + H₂

Combustion

1. Lithium metal is burned in air.
Li + O₂ → Li₂O

2. The hydrocarbon hexane is burned in excess oxygen.
C₆H₁₄ + O₂ → CO₂ + H₂O

3. Gaseous diborane, B₂H₆, is burned in excess oxygen.
B₂H₆ + O₂ → B₂O₃ + H₂O

4. A piece of solid bismuth is heated strongly in oxygen.
Bi + O₂ → Bi₂O₃

5. Solid zinc sulfide is heated in an excess of oxygen.
ZnS + O₂ → ZnO + SO₂

6. Propanol is burned completely in air.
C₃H₇OH + O₂ → CO₂ + H₂O

7. Excess oxygen gas is mixed with ammonia gas in the presence of platinum.
O₂ + NH₃ → NO₂ + H₂O

8. Gaseous silane, SiH₄, is burned in oxygen.
SiH₄ + O₂ → SiO₂ + H₂O

9. Ethanol is completely burned in air.
   C₂H₅OH + O₂ → CO₂ + H₂O

10. Solid copper(II) sulfide is heated strongly in oxygen gas.
    CuS + O₂ → CuO + SO₂

11. Ethanol is burned in oxygen.
    C₂H₅OH + O₂ → CO₂ + H₂O

Redox
1. Iron(III) ions are reduced by iodide ions.
   Fe³⁺ + I⁻ → Fe²⁺ + I₂

2. Potassium permanganate solution is added to concentrated hydrochloric acid.
   MnO₄⁻ + H⁺ + Cl⁻ → Mn²⁺ + Cl₂ + H₂O

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.
   Mg + H⁺ + NO₃⁻ → NH₄⁺ + Mg²⁺ + H₂O

4. A solution of potassium iodide is electrolyzed.
   I⁻ + H₂O → I₂ + H₂ + OH⁻

5. Potassium dichromate solution is added to an acidified solution of sodium sulfite.
   Cr₂O₇²⁻ + SO₃²⁻ + H⁺ → Cr³⁺ + SO₄²⁻ + H₂O

6. Solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.
   I⁻ + IO₃⁻ + H⁺ → H₂O + I₂

7. A solution of tin(II) sulfate is added to a solution of iron(III) sulfate.
   Sn²⁺ + Fe³⁺ → Sn⁴⁺ + Fe²⁺

8. Metallic copper is heated with concentrated sulfuric acid.
   Cu + H₂SO₄ → Cu²⁺ + SO₂ + H₂O

9. Manganese(IV) oxide is added to warm, concentrated hydrobromic acid.
   MnO₂ + H⁺ + Br⁻ → Mn²⁺ + Br₂ + H₂O

10. Chlorine gas is bubbled into cold dilute sodium hydroxide.
    Cl₂ + OH⁻ → ClO⁻ + Cl⁻ + H₂O

11. Solid iron(III) oxide is heated in excess carbon monoxide.
    Fe₂O₃ + CO → Fe + CO₂

12. Hydrogen peroxide solution is added to acidified potassium iodide solution.
    H₂O₂ + H⁺ + I⁻ → H₂O + I₂

13. Hydrogen peroxide is added to an acidified solution of potassium dichromate.
    H₂O₂ + H⁺ + Cr₂O₇²⁻ → H₂O + Cr³⁺ + O₂

14. Sulfur dioxide gas is bubbled through an acidified solution of potassium permanganate.
    SO₂ + H⁺ + MnO₄⁻ → Mn²⁺ + H₂O + SO₄²⁻

15. A solution containing tin(II) ions is added to an acidified solution of potassium dichromate.
    Sn²⁺ + H⁺ + Cr₂O₇²⁻ → Cr³⁺ + Sn⁴⁺ + H₂O

16. Solid silver sulfide is warmed with dilute nitric acid.
    Ag₂S + H⁺ + NO₃⁻ → Ag⁺ + S + NO₂ + H₂O

17. A dilute solution of sulfuric acid is electrolyzed between platinum electrodes.
    H₂O → H₂ + O₂

18. Pellets of lead are dropped into hot sulfuric acid.
    Pb + H⁺ + SO₄²⁻ → H₂O + SO₂ + Pb²⁺ (or PbSO₄ )
19. Potassium permanganate solution is added to a solution of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, acidified with a few drops of sulfuric acid.
\[
\text{MnO}_4^- + \text{H}_2\text{C}_2\text{O}_4 + \text{H}^+ \rightarrow \text{Mn}^{2+} + \text{CO}_2 + \text{H}_2\text{O}
\]
20. Powdered iron is added to a solution of iron(III) sulfate.
\[
\text{Fe} + \text{Fe}^{3+} \rightarrow \text{Fe}^{2+}
\]
21. A concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated.
\[
\text{H}^+ + \text{Cl}^- + \text{MnO}_2 \rightarrow \text{Cl}_2 + \text{Mn}^{2+} + \text{H}_2\text{O}
\]
22. A strip of copper metal is added to a concentrated solution of sulfuric acid.
\[
\text{Cu} + \text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{Cu}^{2+} + \text{SO}_2 + \text{H}_2\text{O}
\]
23. Copper(II) sulfide is oxidized by dilute nitric acid.
\[
\text{CuS} + \text{H}^+ + \text{NO}_3^- \rightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O} + \text{S}
\]
24. A solution of copper(II) sulfate is electrolyzed using inert electrodes.
\[
\text{Cu}^{2+} + \text{H}_2\text{O} \rightarrow \text{O}_2 + \text{H}^+ + \text{Cu}
\]
25. A solution of potassium iodide is added to an acidified solution of potassium dichromate.
\[
\text{I}^- + \text{H}^+ + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{I}_2 + \text{Cr}^{3+} + \text{H}_2\text{O}
\]
26. Hydrogen peroxide solution is added to a solution of iron(II) sulfate.
\[
\text{H}_2\text{O}_2 + \text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{H}_2\text{O}
\]
27. Solid silver is added to a dilute nitric acid (6M) solution.
\[
\text{Ag} + \text{H}^+ + \text{NO}_3^- \rightarrow \text{Ag}^+ + \text{NO} + \text{H}_2\text{O}
\]
28. A solution of formic acid, HCOOH, is oxidized by an acidified solution of potassium dichromate.
\[
\text{HCOOH} + \text{H}^+ + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{H}_2\text{O} + \text{Cr}^{3+} + \text{CO}_2
\]
29. A piece of iron is added to a solution of iron(III) sulfate.
\[
\text{Fe} + \text{Fe}^{3+} \rightarrow \text{Fe}^{2+}
\]
30. An acidified solution of potassium permanganate is added to a solution of sodium sulfite.
\[
\text{H}^+ + \text{MnO}_4^- + \text{SO}_3^{2-} \rightarrow \text{Mn}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{O}
\]
31. A solution of tin(II) chloride is added to a solution of iron(III) sulfate.
\[
\text{Sn}^{2+} + \text{Fe}^{3+} \rightarrow \text{Sn}^{4+} + \text{Fe}^{2+}
\]
32. Concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.
\[
\text{H}^+ + \text{Cl}^- + \text{MnO}_2 \rightarrow \text{Mn}^{2+} + \text{Cl}_2 + \text{H}_2\text{O}
\]
33. A strip of copper is immersed in dilute nitric acid.
\[
\text{Cu} + \text{H}^+ + \text{NO}_3^- \rightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O}
\]
34. Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
\[
\text{MnO}_4^- + \text{H}^+ + \text{H}_2\text{O}_2 \rightarrow \text{Mn}^{2+} + \text{O}_2 + \text{H}_2\text{O}
\]
35. Solid copper is added to a dilute nitric acid solution.
\[
\text{Cu} + \text{H}^+ + \text{NO}_3^- \rightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O}
\]
36. Chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.
\[
\text{Cl}_2 + \text{OH}^- \rightarrow \text{ClO}^- + \text{Cl}^- + \text{H}_2\text{O}
\]
37. A solution of potassium permanganate is mixed with an alkaline solution of sodium sulfite.
\[
\text{MnO}_4^- + \text{OH}^- + \text{SO}_3^{2-} \rightarrow \text{SO}_4^{2-} + \text{H}_2\text{O} + \text{MnO}_4^{2-} \text{ (or MnO}_2\text{)}
\]
38. Solid sodium dichromate is added to an acidified solution of sodium iodide.
\[
\text{Na}_2\text{Cr}_2\text{O}_7 + \text{H}^+ + \text{I}^- \rightarrow \text{Cr}^{3+} + \text{I}_2 + \text{H}_2\text{O} + \text{Na}^+
\]
39. Hydrogen gas is passed over hot iron(III) oxide.
\[ H_2 + Fe_2O_3 \rightarrow Fe + H_2O \]

40. Solutions of potassium iodide and potassium iodate are mixed in acid solution.
\[ I^- + IO_3^- + H^+ \rightarrow I_2 + H_2O \]

41. Hydrogen peroxide is added to an acidified solution of sodium bromide.
\[ H_2O_2 + H^+ + Br^- \rightarrow Br_2 + H_2O \]

42. Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
\[ Cl_2 + OH^- \rightarrow Cl^- + ClO^- + H_2O \]

43. A solution of iron(II) nitrate is exposed to air for an extended period of time.
\[ Fe^{2+} + O_2 \rightarrow Fe_2O_3 \]

**Acid-Base Neutralizations**

1. Solutions of ammonia and hydrofluoric acid are mixed.
\[ NH_3 + HF \rightarrow NH_4^+ + F^- \]

2. Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.
\[ H_2S + OH^- \rightarrow H_2O + S^2^- \]

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.
\[ H^+ + SO_4^{2-} + Ba^{2+} + OH^- \rightarrow H_2O + BaSO_4 \]

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.
\[ OH^- + H_2PO_4^- \rightarrow HPO_4^{2-} + H_2O \]

5. Dilute nitric acid is added to crystals of pure calcium oxide.
\[ H^+ + CaO \rightarrow H_2O + Ca^{2+} \]

6. Equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed.
\[ H^+ + OH^- \rightarrow H_2O \]

7. A solution of ammonia is added to a dilute solution of acetic acid.
\[ NH_3 + HC_2H_3O_2 \rightarrow NH_4^+ + C_2H_3O_2^- \]

8. Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
\[ SO_2 + OH^- \rightarrow H_2O + SO_3^{2-} \]

9. Sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.
\[ SO_2 + Ca^{2+} + OH^- \rightarrow CaSO_3 + H_2O \]

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.
\[ OH^- +Ca^{2+} + HCO_3^- \rightarrow H_2O + CaCO_3 \]

11. Equal volumes of 0.1M hydrochloric acid and 0.1M sodium monohydrogen phosphate are mixed.
\[ H^+ + HPO_4^{2-} \rightarrow H_2PO_4^- \]

12. Hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.
\[ H_2S + OH^- \rightarrow H_2O + S^{2-} \]

13. Ammonia gas and carbon dioxide gas are bubbled into water.
\[ NH_3 + CO_2 + H_2O \rightarrow NH_4^+ + CO_3^{2-} \]

14. Carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.
\[ CO_2 + OH^- \rightarrow CO_3^{2-} + H_2O \]

15. Acetic acid solution is added to a solution of sodium hydrogen carbonate.
\[ HC_2H_3O_2 + HCO_3^- \rightarrow H_2O + CO_2 + C_2H_3O_2^- \]
16. Excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.

\[ \text{OH}^- + H_2\text{PO}_4^- \rightarrow H_2O + \text{PO}_4^{3-} \]

**Complex Ions**

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

\[ \text{NH}_3 + \text{Cu}^{2+} \rightarrow [\text{Cu(NH}_3)_4]^{2+} \]

2. An excess of nitric acid solution is added to a solution of tetraaminecopper(II) sulfate.

\[ \text{H}^+ + [\text{Cu(NH}_3)_4]^{2+} \rightarrow \text{NH}_4^+ + \text{Cu}^{2+} \]

3. Dilute hydrochloric acid is added to a solution of diammoniumsilver(I) nitrate.

\[ \text{H}^+ + \text{Cl}^- + [\text{Ag(NH}_3)_2]^+ \rightarrow \text{AgCl} + \text{NH}_4^+ \]

4. Solid aluminum nitrate is dissolved in water.

\[ \text{Al(NO}_3)_3 + H_2O \rightarrow [\text{Al(H}_2\text{O})_6]^{3+} + \text{NO}_3^- \]

5. A suspension of copper(II) hydroxide is treated with an excess of ammonia water.

\[ \text{Cu(OH)}_2 + \text{NH}_3 \rightarrow [\text{Cu(NH}_3)_4]^{2+} + \text{OH}^- \]

6. A solution of diammoniumsilver(I) chloride is treated with dilute nitric acid.

\[ [\text{Ag(NH}_3)_2]^+ + \text{Cl}^- + \text{H}^+ \rightarrow \text{NH}_4^+ + \text{AgCl} \]

7. An excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.

\[ \text{NH}_3 + \text{Cu(OH)}_2 \rightarrow [\text{Cu(NH}_3)_4]^{2+} + \text{OH}^- \]

8. Excess dilute nitric acid is added to a solution containing the tetraaminecadmium(II) ion.

\[ \text{H}^+ + [\text{Cd(NH}_3)_4]^{2+} \rightarrow \text{NH}_4^+ + \text{Cd}^{2+} \]

9. An excess of ammonia is bubbled through a solution saturated with silver chloride.

\[ \text{NH}_3 + \text{Ag}^{+} \rightarrow [\text{Ag(NH}_3)_2]^+ \]

10. Solid aluminum oxide is added to a solution of sodium hydroxide.

\[ \text{Al}_2\text{O}_3 + \text{OH}^- \rightarrow [\text{Al(OH)}_4]^- \text{ (may have water as a reactant)} \]

11. A concentrated solution of ammonia is added to a solution of zinc iodide.

\[ \text{NH}_3 + \text{Zn}^{2+} \rightarrow [\text{Zn(NH}_3)_4]^{2+} \]

12. An excess of sodium hydroxide solution is added to a solution of aluminum chloride.

\[ \text{OH}^- + \text{Al}^{3+} \rightarrow [\text{Al(OH)}_3]^- \]

13. A concentrated solution of ammonia is added to a solution of copper(II) chloride.

\[ \text{NH}_3 + \text{Cu}^{2+} \rightarrow [\text{Cu(NH}_3)_4]^{2+} \]

14. Excess concentrated sodium hydroxide solution is added to solid aluminum hydroxide.

\[ \text{OH}^- + \text{Al(OH)}_3 \rightarrow [\text{Al(OH)}_4]^- \]

15. Excess concentrated ammonia solution is added to a suspension of silver chloride.

\[ \text{NH}_3 + \text{AgCl} \rightarrow [\text{Ag(NH}_3)_2]^+ + \text{Cl}^- \]

16. Pellets of aluminum metal are added to a solution containing an excess of sodium hydroxide.

\[ \text{Al} + \text{OH}^- \rightarrow [\text{Al(OH)}_4]^- \]

17. A suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.

\[ \text{Zn(OH)}_2 + \text{OH}^- \rightarrow [\text{Zn(OH)}_4]^{2-} \]

18. Silver chloride is dissolved in excess ammonia solution.

\[ \text{AgCl} + \text{NH}_3 \rightarrow [\text{Ag(NH}_3)_2]^+ + \text{Cl}^- \]

19. Sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.

\[ \text{OH}^- + \text{Al(OH)}_3 \rightarrow [\text{Al(OH)}_4]^- \]

20. A drop of potassium thiocyanate is added to a solution of iron(III) chloride.
SCN\(^-\) + Fe\(^{3+}\) → FeSCN\(^{2+}\)

21. A concentrated solution of ammonia is added to a suspension of zinc hydroxide.
   \[ \text{NH}_3 + \text{Zn(OH)}_2 \rightarrow [\text{Zn(NH}_3)_4]^{2+} + \text{OH}^- \]

22. Excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.
   \[ \text{Zn(OH)}_2 + \text{OH}^- \rightarrow [\text{Zn(OH)}_4]^{2-} \]

Addition
1. The gases boron trifluoride and ammonia are mixed.
   \[ \text{BF}_3 + \text{NH}_3 \rightarrow \text{F}_3\text{BNH}_3 \]
2. A mixture of solid calcium oxide and solid tetraphosphorus decaoxide is heated.
   \[ \text{CaO} + \text{P}_4\text{O}_{10} \rightarrow \text{Ca}_3(\text{PO}_4)_2 \]
3. Solid calcium oxide is exposed to a stream of carbon dioxide gas.
   \[ \text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3 \]
4. Solid calcium oxide is heated in the presence of sulfur trioxide gas.
   \[ \text{CaO} + \text{SO}_3 \rightarrow \text{CaSO}_4 \]
5. Calcium metal is heated strongly in nitrogen gas.
   \[ \text{Ca} + \text{N}_2 \rightarrow \text{Ca}_3\text{N}_2 \]
6. Excess chlorine gas is passed over hot iron filings.
   \[ \text{Cl}_2 + \text{Fe} \rightarrow \text{FeCl}_3 \]
7. Powdered magnesium oxide is added to a container of carbon dioxide gas.
   \[ \text{MgO} + \text{CO}_2 \rightarrow \text{MgCO}_3 \]
8. A piece of lithium metal is dropped into a container of nitrogen gas.
   \[ \text{Li} + \text{N}_2 \rightarrow \text{Li}_3\text{N} \]
9. Magnesium metal is burned in nitrogen gas.
   \[ \text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2 \]
10. Sulfur dioxide gas is passed over solid calcium oxide.
    \[ \text{SO}_2 + \text{CaO} \rightarrow \text{CaSO}_3 \]

Decomposition
1. A solution of hydrogen peroxide is heated.
   \[ \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + \text{H}_2\text{O} \]
2. Solid magnesium carbonate is heated.
   \[ \text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2 \]
3. A solution of hydrogen peroxide is catalytically decomposed.
   \[ \text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \text{O}_2 \]
4. Solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst.

\[
\text{KClO}_3 \xrightarrow{MnO_2} \text{KCl} + \text{O}_2
\]

5. Sodium hydrogen carbonate is dissolved in water.

\[
\text{NaHCO}_3 \rightarrow \text{Na}^+ + \text{HCO}_3^-
\]

6. Solid ammonium carbonate is heated.

\[(\text{NH}_4)_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{NH}_3 + \text{H}_2\text{O}\]

ORGANIC

1. A sample of pure 2-butene is treated with hydrogen bromide gas.

\[
\text{C}_4\text{H}_8 + \text{HBr} \rightarrow \text{C}_4\text{H}_9\text{Br}
\]

2. An excess of chlorine gas is added to pure acetylene.

\[
\text{Cl}_2 + 2\text{C}_2\text{H}_2 \rightarrow \text{C}_2\text{H}_2\text{Cl}_4
\]

3. Ethyl acetate is treated with a solution of sodium hydroxide.

\[
\text{CH}_3\text{COOC}_2\text{H}_5 + \text{OH}^- \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{COO}^-
\]

4. Benzene is treated with bromine in the presence of a catalyst.

\[
\text{Br}_2 + \text{C}_6\text{H}_6 \rightarrow \text{C}_6\text{H}_5\text{Br} + \text{HBr}
\]

5. Propene reacts with water in the presence of a catalyst.

\[
\text{C}_3\text{H}_6 + \text{H}_2\text{O} \rightarrow \text{C}_3\text{H}_7\text{OH}
\]

6. Methyl iodide is heated with a solution of sodium hydroxide.

\[
\text{CH}_3\text{I} + \text{OH}^- \rightarrow \text{CH}_3\text{OH} + \text{I}^-
\]

7. Methane gas is heated with an excess of chlorine gas.

\[
\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}
\]

8. Ethanol and formic acid (methanoic acid) are mixed and warmed.

\[
\text{C}_2\text{H}_5\text{OH} + \text{HCOOH} \rightarrow \text{HCOOC}_2\text{H}_5 + \text{H}_2\text{O}
\]

9. Ethene (ethylene) gas is bubbled through a solution of bromine.

\[
\text{C}_2\text{H}_4 + \text{Br}_2 \rightarrow \text{C}_2\text{H}_4\text{Br}_2
\]