The Advanced Placement Examination in Chemistry

Part II - Free Response Questions & Answers 1970 to 2006

Equations

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Equations

Give the formulas to show the reactants and the products for the following chemical reactions. Each 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.

1964

a) $PbCrO_4(s) + Na^+ + OH^- \rightarrow Pb(ONa)_2 + Na_2CrO_4 + H_2O$ [or $PbO_2 + Cr^{3+} \backslash Pb(OH)_2$]

b) $LiH(s) + H_2O \rightarrow Li^+ + OH^- + H_2$

c) $Zn^{2+} + SO_4^{2-} + NH_3(\text{excess}) \rightarrow Zn(NH_3)_2^{2+}$

d) $Na^+ + CH_3COO^- + H^+(\text{excess}) + Cl^- \rightarrow CH_3COOH$

e) $K^+ + Cr_2O_7^{2-} + H^+ + SO_4^{2-} + Na^+ + I^- \rightarrow Cr^{3+} + I_2 + H_2O$

f) $BaCO_3(s) + H^+(\text{excess}) + NO_3^- \rightarrow Ba^{2+} + H_2O + CO_2$

g) $Al_2S_3(s) + H_2O \rightarrow Al(OH)_3 + H_2S$

h) $Ag(s) + H^+ + NO_3^- \rightarrow$ [nitric acid is 6M] $Ag^+ + NO(g) + H_2O$

1965

a) $Zn(s) + Sn^{2+} \rightarrow Sn(s) + Zn^{2+}$

b) $Na^+ + Cr_2O_7^{2-} + Fe^{2+} + SO_4^{2-} + H^+ + SO_4^{2-} \rightarrow Fe^{3+} + Cr^{3+} + H_2O$

c) $TiCl_4(l) + H_2O(l) \rightarrow Ti(OH)_4(s) + H^+(aq) + Cl^-(aq)$

d) $NH_4Cl(s) + Na^+ + OH^- \rightarrow NH_3(g)$ or $(aq) + Cl^-$

e) $NaHCO_3(s) + Na^+ + OH^- \rightarrow Na^+ + CO_3^{2-}(aq) + H_2O$

f) $CaSO_3(s) + H_3O^+ + Cl^- \rightarrow Ca^{2+} + SO_2(g) + H_2O$

g) $Na(s) + NH_3(l)$ (non-aqueous) $\rightarrow Na^+ + NH_2^- + H_2$

h) $CH_3COOH(l) + CH_3OH(l)$ (non-aqueous) $\rightarrow CH_3COOCH_3 + H_2O$

1966

a) $IO_3^- + I^- + H_3O^+ \rightarrow I_2 + H_2O$

b) $Ca_3(PO_4)_2(s) + H_3O^+ + Cl^-$ (excess acid) $\rightarrow H_3PO_4 + Ca^{2+} + H_2O$

c) $NaNH_2(s) + H_2O \rightarrow Na^+(aq) + NH_3(aq) + OH^-(aq)$

d) $Zn(s) + H_3O^+ + Cl^- \rightarrow Zn^{2+} + H_2(g) + H_2O$

e) $Cr_2O_7^{2-} + OH^- \rightarrow CrO_4^{2-} + H_2O$

f) $BaCO_3(s) + CO_2 + H_2O \rightarrow Ba^{2+} + HCO_3^-(aq)$

g) $MnO_4^{2-} + H_3O^+ \rightarrow MnO_4^- + Mn^{2+} + H_2O$

h) $Zn(OH)_2(s) + NH_3(aq) \rightarrow Zn(NH_3)_4^{2+} + OH^-$

1967

a) $PbCl_2(s)$ (moist) $+ H_2S(g) \rightarrow PbS(s) + H^+(aq) + Cl^-(aq)$

b) $NaOH(s)$ (moist) $+ CO_2(g) \rightarrow Na^+(aq) + HCO^{3-}(aq)$

c) $AgCl(s) + NH_3(aq) \rightarrow Ag(NH_3)^{2+}(aq) + Cl^-(aq)$

d) $MnO_4^-(aq) + H^+(aq) + I^-(aq) \rightarrow Mn^{2+}(aq) + H_2O + I_2$

e) $PCl_3 + H_2O \rightarrow H_3PO_3(aq) + H^+(aq) + Cl^-(aq)$

f) $H_2O_2(aq)$ (heated) $\rightarrow H_2O + O_2(g)$

g) $Hg(l) + HNO_3$(conc) $\rightarrow Hg^{2+}(aq) + H_2O + NO_2(g)$

h) $BF_3(g) + (CH_3)_3N(g) \rightarrow (CH_3)_3NBF_3$ {Lewis Acid-Base reaction}

1968

a) iron(III) ions are reduced by iodide ions.
$Fe^{3+}(aq) + I^-(aq) \rightarrow Fe^{2+}(aq) + I_2$ [or $I_3^-(aq)$]

b) hydrogen sulfide is bubbled through a solution of silver nitrate.
$H_2S(aq) + Ag^+(aq) \rightarrow Ag_2S(s) + H^+(aq)$

c) potassium permanganate solution is added to concentrated hydrochloric acid.
$MnO_4^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow Mn^{2+}(aq) + Cl_2(g) + H_2O$

d) concentrated (15M) ammonia solution is added in excess to a solution of copper(II) nitrate.
$NH_3(aq) + Cu^{2+}(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$

e) 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.
$Mg(s) + NO_3^-(aq) + H^+(aq) \rightarrow Mg^{2+}(aq) + NH_4^+(aq)$

f) excess water is added to solid calcium hydride.
$CaH_2(s) + H_2O \rightarrow H_2(g) + Ca^{2+}(aq) + OH^-(aq)$

g) excess silver acetate is added to a solution of trisodium phosphate.
$AgCH_3COO(s) + PO_4^{3-}(aq) \rightarrow CH_3COO^-(aq) + Ag_3PO_4(s)$ [or Ag_2HPO_4 \ AgH_2PO_4]

h) solid sodium cyanide is added to water.
$NaCN(s) + H_2O \rightarrow HCN(aq) + Na^+(aq) + OH^-(aq)$

1969

a) solid potassium hydride is added to anhydrous ethyl alcohol.
$KH(s) + C_2H_5OH \rightarrow K^+ + C_2H_5O^- + H_2(g)$

b) lithium metal is burned in air.
$Li(s) + O_2(g) \rightarrow Li_2O(s)$ \ $Li(s) + N_2(g) \rightarrow Li_3N(s)$

c) aluminum metal is added to a solution of copper(II) chloride.
$Al(s) + Cu^{2+}(aq) \rightarrow Al^{3+}(aq) + Cu(s)$

d) liquid phosphorus trichloride is poured into a large excess of water.
$PCl_3(l) + H_2O \rightarrow H_3PO_3(aq) + H^+(aq) + Cl^-(aq)$

e) manganese(II) nitrate solution is mixed with sodium hydroxide solution.
$Mn^{2+}(aq) + OH^-(aq) \rightarrow Mn(OH)_2(s)$

f) equal volumes of dilute equimolar solutions of sodium carbonate and hydrochloric acid are mixed.
$CO_3^{2-}(aq) + H^+(aq) \rightarrow HCO_3^-(aq)$

g) solid sodium carbide is added to an excess of water.

$Na_2C_2(s) + H_2O \rightarrow C_2H_2(g) + Na^+(aq) + OH^-(aq)$

h) an excess of sodium hydroxide solution is added to a solution of aluminum chloride.

$Al(H_2O)_6^{3+}(aq) + OH^-(aq) \rightarrow AlO_2^-(aq) + H_2O$ [or $Al(OH)_3(aq) \backslash Al(OH)_4^-(aq)$]

1970

a) a mixture of solid calcium oxide and solid tetraphosphorus decaoxide is heated.

$CaO(s) + P_4O_{10}(s) \rightarrow Ca_3(PO_4)_2(s)$

b) solid barium peroxide is added to cold dilute sulfuric acid.

$BaO_2(s) + H^+(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + H_2O_2(aq)$

c) dilute acetic acid solution is added to solid magnesium carbonate.

$CH_3COOH(aq) + MgCO_3(s) \rightarrow H_2O + CO_2(g) + Mg^{2+}(aq) + CH_3COO^-(aq)$

d) the hydrocarbon hexane is burned in excess oxygen.

$C_6H_{14}(l) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

e) solid magnesium nitride is added to excess deuterium oxide.

$Mg_3N_2(s) + D_2O \rightarrow ND_3 + Mg(OD)_2(s)$ [or $MgO(s) \backslash Mg^{2+}(aq) + OD^-(aq)$]

f) gaseous hydrofluoric acid reacts with solid silicon dioxide

$HF(g) + SiO_2(s) \rightarrow SiF_4 + H_2O$

g) potassium dichromate solution is added to an acidified solution of sodium sulfite.

$Cr_2O_7^{2-}(aq) + HSO_3^-(aq) \rightarrow SO_4^{2-}(aq) + Cr^{3+}(aq) + H_2O$

h) dilute hydrochloric acid is added to a solution of diamminesilver(I) nitrate

$H^+(aq) + Cl^-(aq) + [Ag(NH_3)_2]^+(aq) \rightarrow AgCl(s) + NH_4^+(aq)$

1971

a) equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.

$PO_4^{3-}(aq) + H^+(aq) \rightarrow HPO_4^{2-}(aq)$

b) propene gas is mixed with bromine vapor.

$C_3H_6(g) + Br_2(g) \rightarrow C_3H_6Br_2$

c) solid aluminum nitrate is dissolved in water.

$Al(NO_3)_3(s) + H_2O \rightarrow Al(H_2O)_6^{3+}(aq) + NO_3^-(aq)$

d) solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.

$I^-(aq) + IO_3^-(aq) + H^+(aq) \rightarrow H_2O + I_2(aq)$ [or $I_3^-(aq)$]

e) a solution of tin(II) sulfate is added to a solution of iron(III) sulfate.

$Sn^{2+}(aq) + Fe^{3+}(aq) \rightarrow Sn^{4+}(aq) + Fe^{2+}(aq)$

f) a suspension of copper(II) hydroxide is treated with an excess of ammonia water.

$Cu(OH)_2(s) + NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq) + OH^-(aq)$

g) a saturated solution of calcium hydroxide is added to a solution of magnesium chloride.

$OH^-(aq) + Mg^{2+}(aq) \rightarrow Mg(OH)_2(s)$

h) solid silver sulfide is warmed with dilute nitric acid.

$Ag_2S(s) + H^+(aq) + NO_3^-(aq) \rightarrow Ag^+(aq) + S(s) + NO_2(g) + H_2O$

1972

a) hydrogen gas is passed over hot copper(II) oxide.
$H_2(g) + CuO(s) \rightarrow H_2O(g) + Cu(s)$

b) solid zinc sulfide is heated in an excess of oxygen.
$ZnS(s) + O_2(g) \rightarrow ZnO(s) + SO_2(g)$

c) a limited amount of liquid bromine is added to an excess of benzene.
$Br_2(l) + C_6H_6(l) \rightarrow C_6H_5Br + HBr$

d) a solution of diamminesilver(I) chloride is treated with dilute nitric acid.
$[Ag(NH_3)_2]^+(aq) + Cl^-(aq) + H^+ \rightarrow AgCl(s) + NH_4^+(aq)$

e) metallic copper is heated with concentrated sulfuric acid.
$Cu(s) + H_2SO_4 \rightarrow Cu^{2+} + SO_2 + H_2O$

f) sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.
$SO_2(g) + Ca(OH)_2(aq) \rightarrow CaSO_3(s) + H_2O$

g) manganese(IV) oxide is added to warm, concentrated hydrobromic acid.
$MnO_2(s) + H^+(aq) + Br^-(aq) \rightarrow Mn^{2+} + Br_2 + H_2O$

h) hydrogen sulfide gas is added to a solution of cadmium nitrate.
$H_2S + Cd^{2+} \rightarrow CdS(s) + H^+$

1973

a) chlorine gas is bubbled into cold dilute sodium hydroxide.
$Cl_2(g) + OH^-(aq) \rightarrow ClO^-(aq) + Cl^-(aq) + H_2O$

b) solid iron(III) oxide is heated in excess carbon monoxide.
$Fe_2O_3(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$

c) solid magnesium carbonate is heated.
$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

d) trisodium phosphate crystals are added to water.
$Na_3PO_4(s) + H_2O \rightarrow Na^+(aq) + OH^-(aq) + HPO_4^{2-}(aq)$ [or $H_2PO_4^-(aq)$]

e) gaseous diborane, B_2H_6, is burned in excess oxygen.
$B_2H_6(g) + O_2(g) \rightarrow H_2O + B_2O_3$ [or H_3BO_3]

f) small chunks of solid sodium are added to water.
$Na(s) + H_2O \rightarrow Na^+(aq) + OH^-(aq) + H_2(g)$

g) hydrogen peroxide solution is added to acidified potassium iodide solution.
$H_2O_2(aq) + H^+(aq) + I^-(aq) \rightarrow H_2O + I_2(aq)$ or $I_3^-(aq)$]

h) pure methyl alcohol and pure acetic acid are mixed.
$CH_3OH + CH_3COOH \rightarrow CH_3COOCH_3 + H_2O$

i) an excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.
$NH_3(aq) + Cu(OH)_2(s) \rightarrow [Cu(NH_3)_4]^{2+}(aq) + OH^-(aq)$

1974

a) a sample of pure 2-butene is treated with hydrogen bromide gas.

$C_4H_8(g) + HBr(g) \rightarrow C_4H_9Br$

b) water is added to a sample of pure phosphorus tribromide.

$H_2O + PBr_3(s) + H_3PO_3(aq) + H^+(aq) + Br^-(aq)$

c) hydrogen peroxide is added to an acidified solution of potassium dichromate.

$H_2O_2 + H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq) + H_2O + O_2(g)$

d) calcium metal is added to a dilute solution of hydrochloric acid.

$Ca(s) + H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$

e) 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.

$H^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + OH^-(aq) \rightarrow BaSO_4(s) + H_2O$

f) excess dilute nitric acid is added containing the tetraaminecadmium(II) ion.

$H^+(aq) + [Cd(NH_3)_4]^{2+}(aq) \rightarrow Cd^{2+}(aq) + NH_4^+(aq)$

g) sulfur dioxide gas is bubble through an acidified solution of potassium permanganate.

$SO_2(g) + H^+(aq) + MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + H_2O + SO_4^{2-}(aq)$

h) pellets of aluminum metal are added to a solution containing an excess of sodium hydroxide.

$Al(s) + OH^-(aq) \rightarrow AlO_2^-(aq) + H_2O + H_2(g)$ [or $Al(OH)_4^-(aq) \backslash Al(OH)_6^{3-}(aq)$]

i) a solution of sodium hydroxide is added to a solution of sodium dihydrogen phosphate until the same number of moles of each compound had been added.

$OH^-(aq) + H_2PO_4^-(aq) \rightarrow H_2O + HPO_4^{2-}(aq)$

1975

a) a solution containing tin(II) ions is added to an acidified solution of potassium dichromate.

$Sn^{2+}(aq) + H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow Sn^{4+}(aq) + Cr^{3+}(aq) + H_2O$

b) liquid bromine is added to a solution of potassium iodide.

$Br_2(l) + I^-(aq) \rightarrow Br^-(aq) + I_2(aq)$ [or $I_3^-(aq)$]

c) an excess of ammonia gas is bubbled through a solution saturated with silver chloride.

$NH_3(g) + Ag^+(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$

d) water is added to a sample of pure sodium hydride.

$NaH + H_2O \rightarrow Na^+(aq) + H_2(g) + OH^-(aq)$

e) an excess of chlorine gas is added to pure acetylene.

$Cl_2(g) + C_2H_2(g) \rightarrow C_2H_2Cl_4$

f) a dilute solution of sulfuric acid is electrolyzed between platinum electrodes.

$H_2O \rightarrow H_2(g) + O_2(g)$

g) excess oxygen gas is mixed with ammonia gas in the presence of platinum.

$O_2(g) + NH_3(g) \rightarrow NO_2 + H_2O$

h) dilute nitric acid is added to crystals of pure calcium oxide.

$H^+(aq) + CaO(s) \rightarrow Ca^{2+}(aq) + H_2O$

i) 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.

$OH^{-}(aq) + HCO_3^{2-}(aq) \rightarrow H_2O + CO_3^{2-}(aq)$

1976

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

$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$

b) dinitrogen trioxide gas is bubbled into water.

$N_2O_3(g) + H_2O \rightarrow HNO_2(aq)$

c) sodium hydrogen carbonate is dissolved in water.

$NaHCO_3(s) + H_2O \rightarrow Na^{+}(aq) + HCO_3^{-}(aq)$ [or $H_2CO_3(aq) + OH^{-}(aq)$]

d) pellets of lead are dropped into hot sulfuric acid.

$Pb(s) + H^{+}(aq) + SO_4^{2-}(aq) \rightarrow H_2O + SO_2(g) + Pb^{2+}(aq)$ [or $PbSO_4$]

e) potassium permanganate solution is added to a solution of oxalic acid, $H_2C_2O_4$, acidified with a few drops of sulfuric acid.

$MnO_4^{-}(aq) + H_2C_2O_4 + H^{+}(aq) \rightarrow Mn^{2+}(aq) + H_2O + CO_2(g)$

f) magnesium turnings are added to a solution of iron(III) chloride.

$Mg(s) + Fe^{3+}(aq) \rightarrow Mg^{2+}(aq) + Fe^{2+}(aq)$

g) ethyl acetate is treated with a solution of sodium hydroxide.

$CH_3COOC_2H_5 + OH^{-}(aq) \rightarrow C_2H_5OH(aq) + CH_3COO^{-}(aq)$

h) a suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.

$Zn(OH)_2 + OH^{-}(aq) \rightarrow ZnO_2^{2-}(aq) + H_2O$ [or $Zn(OH)_3^{-}(aq)$]

1977

a) dilute sulfuric acid is added to a solution of barium acetate.

$H^{+}(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + CH_3COO^{-}(aq) \rightarrow BaSO_4(s) + CH_3COOH(aq)$

b) ammonium chloride crystals are added to a solution of sodium hydroxide.

$NH_4Cl(s) + OH^{-}(aq) \rightarrow NH_3(aq) + H_2O + Cl^{-}(aq)$

c) solid phosphorus pentachloride is added to excess water.

$PCl_5(s) + H_2O \rightarrow H_3PO_4(aq) + H_2O + H^{+}(aq) + Cl^{-}(aq)$

d) a solution of hydrogen peroxide is catalytically decomposed.

$H_2O_2 \rightarrow H_2O + O_2$

e) powdered iron is added to a solution of iron(III) sulfate.

$Fe(s) + Fe^{3+}(aq) \rightarrow Fe^{2+}(aq)$

f) chlorine gas is bubbled into a solution of sodium bromide.

$Cl_2(g) + Br^{-}(aq) \rightarrow Cl^{-}(aq) + Br_2$

g) a precipitate is formed when solutions of trisodium phosphate and calcium chloride are mixed.

$PO_4^{3-}(aq) + Ca^{2+}(aq) \rightarrow Ca_3(PO_4)_2(s)$

h) benzene is treated with bromine in the presence of a catalyst.

$Br_2 + C_6H_6 \rightarrow C_6H_5Br + HBr$

1978

a) gaseous silane, SiH_4, is burned in oxygen.
$SiH_4(g) + O_2(g) \rightarrow SiO_2(s) + H_2O$

b) equal volumes of 0.1M hydrochloric acid and 0.1M sodium monohydrogen phosphate are mixed.
$H^+(aq) + HPO_4^{2-}(aq) \rightarrow H_2PO_4^-(aq)$

c) hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.
$H_2S(s) + Pb^{2+}(aq) \rightarrow PbS(s) + H^+(aq)$

d) solid zinc strips are added to a solution of copper(II) sulfate.
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

e) solid lithium oxide is added to excess water.
$Li_2O(s) + H_2O \rightarrow Li^+(aq) + OH^-(aq)$

f) copper(II) sulfide is oxidized by dilute nitric acid
$CuS(s) + H^+(aq) + NO_3^-(aq) \rightarrow Cu^{2+}(aq) + SO_2 + NO + H_2O$

g) silver chloride is dissolved in excess ammonia solution.
$AgCl(s) + NH_3(aq) \rightarrow [Ag(NH_3)_2]^+(aq) + Cl^-(aq)$

h) propene reacts with water in the presence of a catalyst.
$C_3H_6 + H_2O \rightarrow C_3H_7OH$

1979

a) a solution of copper(II) sulfate is electrolyzed using inert electrodes.
$Cu^{2+}(aq) + H_2O \rightarrow Cu(s) + O_2(g) + H^+(aq)$

b) hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.
$H_2S(g) + OH^-(aq) \rightarrow S^{2-}(aq) + H_2O$

c) solutions of silver nitrate and sodium chromate are mixed.
$Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$

d) sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.
$Al(OH)_3(s) + OH^-(aq) \rightarrow H_2O + AlO_2^-(aq)$ [or $Al(OH)_4^-$]

e) solid sodium sulfite is added to water.
$Na_2SO_3(s) + H_2O \rightarrow Na^+(aq) + HSO_3^-(aq) + OH^-(aq)$

f) a solution of formic acid, HCOOH, is oxidized by an acidified solution of potassium dichromate.
$HCOOH(aq) + H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow CO_2(g) + H_2O + Cr^{3+}(aq)$

g) ammonia gas and carbon dioxide gas are bubbled into water.
$NH_3(g) + CO_2(g) + H_2O \rightarrow \{NH_4OH + H_2CO_3\} \rightarrow NH_4^+(aq) + CO_3^{2-}(aq)$

h) concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.
$HCl + MnO_2 \rightarrow Cl_2(g) + Mn^{2+}(aq) + H_2O$

1980

a) solutions of sodium fluoride and dilute hydrochloric acid are mixed.

$F^{-}(aq) + H^{+}(aq) \rightarrow HF(aq)$

b) a saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.

$Ba^{2+}(aq) + OH^{-}(aq) + Fe^{3+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + Fe(OH)_3(s)$

c) a solution of ammonium sulfate is added to a potassium hydroxide solution.

$NH_4^{+}(aq) + OH^{-}(aq) \rightarrow NH_3(aq) + H_2O$

d) carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.

$\{ CO_2 + H_2O \_ H_2CO_3 \}$ $H_2CO_3 + OH^{-} \rightarrow CO_3^{2-} + H_2O$

e) solid copper is added to a dilute nitric acid solution.

$Cu(s) + H^{+}(aq) + NO_3^{-}(aq) \rightarrow Cu^{2+}(aq) + H_2O + NO(g)$

f) chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.

$Cl_2(g) + OH^{-}(aq) \rightarrow ClO^{-}(aq) + Cl^{-}(aq) + H_2O$

g) a solution of potassium permanganate is mixed with an alkaline solution of sodium sulfite.

$MnO_4^{-}(aq) + OH^{-}(aq) + SO_3^{2-}(aq) \rightarrow SO_4^{2-}(aq) + H_2O + MnO_4^{2-}(aq)$ [or $MnO_2(s)$]

h) methyl iodide is heated with a solution of sodium hydroxide.

$CH_3I + OH^{-} \rightarrow CH_3OH + I^{-}$

1981

a) magnesium metal is burned in nitrogen gas.

$Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$

b) sulfur dioxide gas is passed over solid calcium oxide.

$SO_2(g) + CaO(s) \rightarrow CaSO_3(s)$

c) lead foil is immersed in silver nitrate solution.

$Pb(s) + Ag^{+}(aq) \rightarrow Pb^{2+}(aq) + Ag(s)$

d) a solution of ammonium sulfate is added to a saturated solution of barium hydroxide.

$NH_4^{+}(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + OH^{-}(aq) \rightarrow BaSO_4(s) + NH_3(aq) + H_2O$

e) acetic acid solution is added to a solution of sodium hydrogen carbonate.

$CH_3COOH(aq) + HCO_3^{-}(aq) \rightarrow CH_3COO^{-}(aq) + H_2O + CO_2(g)$

f) solid sodium dichromate is added to an acidified solution of sodium iodide.

$Na_2Cr_2O_7(s) + H^{+}(aq) + I^{-}(aq) \rightarrow Na^{+}(aq) + Cr^{3+}(aq) + H_2O + I^{-}(aq)$ [or $I_3^{-}(aq)$]

g) a drop of potassium thiocyanate is added to a solution of iron(III) chloride.

$SCN^{-}(aq) + Fe^{3+}(aq) \rightarrow FeSCN^{2+}(aq)$

h) ethanol is completely burned in air.

$C_2H_5OH + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

1982

a) hydrogen gas is passed over hot iron(III) oxide.

$H_2(g) + Fe_2O_3(s) \rightarrow Fe(s) + H_2O(g)$

b) solutions of potassium iodide and potassium iodate are mixed in acid solution.

$I^{-}(aq) + IO_3^{-}(aq) + H^{+}(aq) \rightarrow I_2(aq) + H_2O$ [or $I_3^{-}(aq)$]

c) dilute sulfuric acid is added to solid calcium fluoride.

$H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + CaF_{2(s)} \rightarrow CaSO_{4(s)} + HF_{(aq)}$

d) solid ammonium carbonate is heated.

$(NH_4)_2CO_{3(s)} \rightarrow NH_{3(g)} + CO_{2(g)} + H_2O_{(g)}$

e) methane gas is heated with an excess of chlorine gas.

$CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl + HCl$

f) a concentrated solution of ammonia is added to a suspension of zinc hydroxide.

$NH_{3(aq)} + Zn(OH)_{2(s)} \rightarrow [Zn(NH_3)_4]^{2+}{}_{(aq)} + OH^-{}_{(aq)}$

g) hydrogen peroxide is added to an acidified solution of sodium bromide.

$H_2O_2 + H^+{}_{(aq)} + Br^-{}_{(aq)} \rightarrow Br_{2(aq)} + H_2O$

h) dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.

$Cl^-{}_{(aq)} + Hg_2^{2+}{}_{(aq)} \rightarrow Hg_2Cl_{2(s)}$

1985

a) sodium metal is added to water.

$Na_{(s)} + H_2O \rightarrow Na^+{}_{(aq)} + OH^-{}_{(aq)} + H_{2(g)}$

b) dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.

$H^+{}_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow H_2O + CO_{2(g)}$

c) ethanol and formic acid (methanoic acid) are mixed and warmed.

$C_2H_5OH + HCOOH \rightarrow HCOOC_2H_5 + H_2O$

d) excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.

$OH^-{}_{(aq)} + Zn(OH)_{2(s)} \rightarrow H_2O + ZnO_2^{2-}{}_{(aq)}$ [or $Zn(OH)_4^{2-}{}_{(aq)}$]

e) the gases boron trifluoride and ammonia are mixed.

$BF_{3(g)} + NH_{3(g)} \rightarrow F_3B{:}NH_3$ {Lewis acid-base reaction}

f) a solution of tin(II) chloride is added to a solution of iron(III) sulfate.

$Sn^{2+}{}_{(aq)} + Fe^{3+}{}_{(aq)} \rightarrow Sn^{4+}{}_{(aq)} + Fe^{2+}{}_{(aq)}$

g) phosphorus(V) oxytrichloride is added to water.

$POCl_3 + H_2O \rightarrow H_3PO_{4(aq)} + H^+{}_{(aq)} + Cl^-{}_{(aq)}$

h) an acidified solution of potassium permanganate is added to a solution of sodium sulfite.

$H^+{}_{(aq)} + MnO_4^-{}_{(aq)} + SO_3^{2-}{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + H_2O$

1986

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

$Li_{(s)} + N_{2(g)} \rightarrow Li_3N$

b) dilute hydrochloric acid is added to a solution of potassium sulfite.

$H^+{}_{(aq)} + SO_3^{2-}{}_{(aq)} \rightarrow HSO_3^-{}_{(aq)}$

c) solid sodium oxide is added to water.

$Na_2O_{(s)} + H_2O \rightarrow Na^+{}_{(aq)} + OH^-{}_{(aq)}$

d) a solution of sodium sulfide is added to a solution of zinc nitrate.

$S^{2-}(aq) + Zn^{2+}(aq) \rightarrow ZnS(s)$

e) a solution of ammonia is added to a dilute solution of acetic acid.

$NH_3(aq) + CH_3COOH(aq) \rightarrow NH_4^+(aq) + CH_3COO^-(aq)$

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

$Fe(s) + Fe^{3+}(aq) \rightarrow Fe^{2+}(aq)$

g) ethene (ethylene) gas is bubbled through a solution of bromine.

$C_2H_4(g) + Br_2 \rightarrow C_2H_4Br_2$

h) chlorine gas is bubbled into a solution of potassium iodide.

$Cl_2(g) + I^-(aq) \rightarrow Cl^-(aq) + I_2(aq)$ [or $I_3^-(aq)$]

1987

a) solid calcium is added to warm water.

$Ca(s) + H_2O \rightarrow Ca^{2+}(aq) + OH^-(aq) + H_2(g)$

b) powdered magnesium oxide is added to a container of carbon dioxide gas.

$MgO(s) + CO_2(g) \rightarrow MgCO_3(s)$

c) gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.

$H_2S(g) + Ni^{2+}(aq) \rightarrow NiS(s) + H^+(aq)$

d) excess concentrated sodium hydroxide solution is added to solid aluminum hydroxide.

$OH^-(aq) + Al(OH)_3(s) \rightarrow H^+(aq) + AlO_2^-(aq)$ [or $Al(OH)_4^-$ \ $Al(OH)_6^{3-}$ \ $Al(OH)_4(H_2O)_2^-$]

e) solid silver is added to a dilute nitric acid (6M) solution.

$Ag(s) + H^+(aq) + NO_3^-(aq) \rightarrow Ag^+(aq) + NO(g) + H_2O$

f) excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.

$OH^-(aq) + H_2PO_4^-(aq) \rightarrow PO_4^{3-}(aq) + H_2O$

g) hydrogen peroxide solution is added to a solution of iron(II) sulfate.

$H_2O_2(aq) + Fe^{2+}(aq) \rightarrow H_2O + Fe^{3+}(aq)$ [or $Fe(OH)_3(s)$]

h) propanol is burned completely in air.

$C_3H_7OH(l) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

1988

a) a solution of potassium iodide is added to an acidified solution of potassium dichromate.

$H^+(aq) + I^-(aq) + Cr_2O_7^{2-}(aq) \rightarrow I_2(aq) + Cr^{3+}(aq) + H_2O$ (any reasonable I^- oxidation prod. accepted)

b) a solution of sodium hydroxide is added to a solution of ammonium chloride.

$OH^-(aq) + NH_4^+(aq) \rightarrow H_2O + NH_3(aq)$ [or $NH_4OH(aq)$]

c) a strip of magnesium is added to a solution of silver nitrate.

$Mg(s) + Ag^+(aq) \rightarrow Mg^{2+}(aq) + Ag(s)$

d) solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst.

$KClO_3(s) \rightarrow KCl(s) + O_2(g)$ (MnO_2 over arrow)

e) dilute hydrochloric acid is added to a solution of potassium carbonate.

$H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O$ (or $H_2CO_3(aq)$ or $HCO_3^-(aq)$)

f) sulfur trioxide gas is added to excess water.
$SO_3(g) + H_2O \rightarrow H^+(aq) + HSO_4^-(aq)$ {or $H^+(aq) + SO_4^{2-}(aq)$}

g) dilute sulfuric acid is added to a solution of barium chloride.
$SO_4^{2-}(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s)$ [or $HSO_4^-(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s) + H^+(aq)$

h) a concentrated solution of ammonia is added to a solution of copper(II) chloride.
$Cu^{2+} + NH_3 \rightarrow Cu(NH_3)_4^{2+}$ {partial for $Cu(OH)_2$}

1989

a) solutions of zinc sulfate and sodium phosphate are mixed.
$Zn^{2+}(aq) + PO_4^{3-}(aq) \rightarrow Zn_3(PO_4)_2(s)$ {or $ZnHPO_4$}

b) solutions of silver nitrate and lithium bromide are mixed.
$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

c) a stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.
$Cl_2(g) + OH^-(aq) \rightarrow OCl^-(aq) + Cl^-(aq) + H_2O$

d) excess hydrochloric acid solution is added to a solution of potassium sulfite.
$H^+(aq) + SO_3^{2-}(aq) \rightarrow H_2O + SO_2$ [or H_2SO_3]

e) a solution of tin(II) chloride is added to an acidified solution of potassium permanganate.
$Sn^{2+}(aq) + H^+(aq) + MnO_4^-(aq) \rightarrow Sn^{4+}(aq) + Mn^{2+}(aq) + H_2O$

f) a solution of ammonium thiocyanate is added to a solution of iron(III) chloride.
$Fe^{3+}(aq) + SCN^-(aq) \rightarrow Fe(SCN)^{2+}(aq)$ [or $Fe(SCN)_6^{3-}(aq)$]

g) samples of boron trichloride gas and ammonia gas are mixed.
$BCl_3 + NH_3 \rightarrow Cl_3B{:}NH_3$ {Lewis Acid-Base}

h) carbon disulfide vapor is burned in excess oxygen.
$CS_2(g) + O_2(g) \rightarrow CO_2(g) + SO_2(g)$ [or $SO_3(g)$]

1990

a) solutions of sodium iodide and lead nitrate are mixed.
$I^-(aq) + Pb^{2+}(aq) \rightarrow PbI_2(s)$

b) a solution of ammonia is added to a solution of ferric chloride.
$OH^-(aq) + Fe^{3+}(aq) \rightarrow Fe(OH)_3(s)$

c) a solution of hydrogen peroxide is heated.
$H_2O_2(aq) \rightarrow H_2O + O_2(g)$

d) solutions of silver nitrate and sodium chromate are mixed.
$Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$

e) hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.
$H_2S + OH^-(aq) \rightarrow S^{2-}(aq) + H_2O$

f) solid dinitrogen pentoxide is added to water.
$N_2O_5(s) + H_2O \rightarrow H^+(aq) + NO_3^-(aq)$

g) a piece of solid bismuth is heated strongly in oxygen.
$Bi(s) + O_2(g) \rightarrow Bi_2O_3(s)$

h) a strip of copper metal is added to a concentrated solution of sulfuric acid.
$Cu_{(s)} + H^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)}$ {or $Cu^+{}_{(aq)}$} $+ H_2O + SO_2$

1991 C

a) solid aluminum oxide is added to a solution of sodium hydroxide.
$Al_2O_{3(s)} + OH^-{}_{(aq)} \rightarrow [Al(OH)_4]^-{}_{(aq)}$ or $Al_2O_{3(s)} + H_2O \rightarrow Al(OH)_{3(s)}$

b) solid calcium oxide is heated in the presence of sulfur trioxide gas.
$CaO_{(s)} + SO_{3(g)} \rightarrow CaSO_{4(s)}$

c) equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed.
$H^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow H_2O$

d) calcium metal is heated strongly in nitrogen gas.
$Ca_{(s)} + N_{2(g)} \rightarrow Ca_3N_{2(s)}$

e) solid copper(II) sulfide is heated strongly in oxygen gas.
$CuS_{(s)} + O_{2(g)} \rightarrow Cu_{(s)} + SO_{2(g)}$ {or $CuO_{(s)}$\$Cu_2O_{(s)}$}

f) a concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated.
$MnO_{2(s)} + H^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + H_2O + Cl_{2(g)}$

g) a concentrated solution of ammonia is added to a solution of zinc iodide.
$Zn^{2+}{}_{(aq)} + NH_{3(aq)} \rightarrow [Zn(NH_3)_4]^{2+}{}_{(aq)}$ or $Zn^{2+}{}_{(aq)} + NH_{3(aq)} + H_2O \rightarrow Zn(OH)_{2(s)} + NH_4^+{}_{(aq)}$

h) a solution of copper(II) sulfate is added to a solution of barium hydroxide.
$Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} + OH^-{}_{(aq)} \rightarrow Cu(OH)_{2(s)} + BaSO_{4(s)}$

1992 C

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

b) solid lithium hydride is added to water.
$LiH + H_2O \rightarrow Li^+ + OH^- + H_2$

c) solutions of ammonia and hydrofluoric acid are mixed.
$NH_3 + HF \rightarrow NH_4^+ + F^-$

d) a piece of aluminum metal is added to a solution of silver nitrate.
$Al + Ag^+ \rightarrow Al^{3+} + Ag$

e) a solution of potassium iodide is electrolyzed.
$I^- + H_2O \rightarrow I_2$ (or I_3^-) $+ H_2 + OH^-$

f) solid potassium oxide is added to water.
$K_2O + H_2O \rightarrow K^+ + OH^-$

g) an excess of nitric acid solution is added to a solution of tetraamminecopper(II) sulfate.
$H^+ + Cu(NH_3)_4^{2+} \rightarrow Cu^{2+} + NH_4^+$

h) carbon dioxide gas is bubbled through water contain a suspension of calcium carbonate.
$CO_2 + H_2O$ (or H_2CO_3) $+ CaCO_3 \rightarrow Ca^{2+} + HCO_3^-$

Equations

1993 C

a) A strip of copper is immersed in dilute nitric acid.
$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO$ (or NO_2) $+ H_2O$

b) Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
$MnO_4^- + H_2O_2 \rightarrow Mn^{2+} + O_2 + H_2O$

c) Concentrated hydrochloric acid is added to solid manganese (II) sulfide.
$H^+ + MnS \rightarrow H_2S + Mn^{2+}$

d) Excess chlorine gas is passed over hot iron filings.
$Fe + Cl_2 \rightarrow FeCl_3$

e) Water is added to a sample of solid magnesium nitride.
$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2$ (or $Mg^{2+} + OH^-$)$+ NH_3$

f) Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
$SO_2 + OH^- \rightarrow HSO_3^-$

g) Excess concentrated ammonia solution is added to a suspension of silver chloride.
$AgCl + NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^-$

h) Solution of tri-potassium phosphate and zinc nitrate are mixed.
$Zn^{2+} + PO_4^{3-} \rightarrow Zn_3(PO_4)_2$

1994 C

a) Excess sodium cyanide solution is added to a solution of silver nitrate.
$CN^- + Ag^+ \rightarrow Ag(CN)_2^-$

b) Solutions of manganese(II) sulfate and ammonium sulfide are mixed.
$Mn^{2+} + S^{2-} \rightarrow MnS_{(s)}$

c) Phosphorus(V) oxide powder is sprinkled over distilled water.
P_4O_{10} (or P_2O_5) $+ H_2O \rightarrow H_3PO_4$

d) Solid ammonium carbonate is heated.
$(NH_4)_2CO_3 \rightarrow NH_3 + CO_2 + H_2O$

e) Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide.
$CO_2 + OH^- \rightarrow CO_3^{2-} + H_2O$

f) A concentrated solution of hydrochloric acid is added to solid potassium permanganate.
$KMnO_4 + H^+ + Cl^- \rightarrow Cl_2 + Mn^{2+} + H_2O + K^+$

g) A small piece of sodium metal is added to distilled water.
$Na + H_2O \rightarrow Na^+ + OH^- + H_2$

h) A solution of potassium dichromate is added to an acidified solution of iron(II) chloride.
$Cr_2O_7^{2-} + H^+ + Fe^{2+} \rightarrow Cr^{3+} + H_2O + Fe^{3+}$

1995 C

a) Ethanol is burned in oxygen.
$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

b) Solid barium oxide is added to distilled water.
$BaO + H_2O \rightarrow Ba^{2+} + OH^-$

c) Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
$Cl_2 + OH^- \rightarrow Cl^- + ClO^-$ (or $ClO^-/ClO_2^-/ClO_3^-$) $+ H_2O$

d) A solution of iron(II) nitrate is exposed to air for an extended period of time.
$Fe^{2+} + O_2$ (+ H_2O) $\rightarrow Fe_2O_3$ or $FeO(OH)$ or $Fe(OH)_3$

e) Excess concentrated sulfuric acid is added to solid calcium phosphate.
$H^+ + SO_4^{2-} + Ca_3(PO_4)_2 \rightarrow CaSO_4$ (or ions) $+ H_3PO_4$

f) Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.
$H_2S + Hg^{2+} \rightarrow HgS + H^+$ or
$H_2S + HgCl_2 \rightarrow HgS + H^+ + Cl^-$

g) Solid calcium hydride is added to distilled water.
$CaH_2 + H_2O \rightarrow Ca(OH)_2$ [or $Ca^{2+} + OH^-$] $+ H_2$

h) A bar of zinc metal is immersed in a solution of cupper(II) sulfate.
$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

1996 C

a) solid calcium carbonate is strongly heated.
$CaCO_3 \rightarrow CaO + CO_2$

b) a piece of nickel metal is immersed in a solution of copper(II) sulfate.
$Ni + Cu^{2+} \rightarrow Ni^{2+} + Cu$

c) equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed.
$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$

d) chlorine gas is bubbled into a solution of sodium bromide.
$Cl_2 + Br^- \rightarrow Cl^- + Br_2$

e) ammonia gas is bubbled into a solution of ethanoic (acetic) acid.
$NH_3 + CH_3COOH \rightarrow NH_4^+ + CH_3COO^-$

f) solid ammonium carbonate is added to a saturated solution of barium hydroxide.
$(NH_4)_2CO_3 + Ba^{2+} + OH^- \rightarrow NH_3 + BaCO_3 + H_2O$

g) drops of liquid dinitrogen trioxide are added to distilled water.
$N_2O_3 + H_2O \rightarrow HNO_2$

h) solutions of potassium permanganate and sodium oxalate are mixed.
$MnO_4^- + C_2O_4^{2-} \rightarrow MnO_2 + CO_2$

1997 C

a) excess potassium hydroxide solution is added to a solution of aluminum nitrate.
$OH^- + Al^{3+} \rightarrow Al(OH)_3$ (*or* $Al(OH)_4^-$; $Al(OH)_4(H_2O)_2^-$; Al_2O_3; $Al_2O_3 \cdot x\ H_2O$; AlO_2^-)

b) a solution of sodium bromide is added to an acidified solution of potassium bromate.
$Br^- + H^+ + BrO_3^- \rightarrow Br_2 + H_2O$

c) sulfur dioxide gas is bubbled into distilled water.

$SO_2 + H_2O \rightarrow H_2SO_3$ (*or* $\rightarrow H^+ + HSO_3^-$; *or* $\rightarrow H^+ + HSO_3^- + SO_3^{2-}$)

d) phosphine (phosphorus trihydride) gas is bubbled into liquid boron trichloride.

$PH_3 + BCl_3 \rightarrow PH_3BCl_3$

e) hydrogen gas is passed over hot iron(II) oxide powder.

$H_2 + FeO \rightarrow Fe + H_2O$

f) solid potassium amide is added to distilled water.

$KNH_2 + H_2O \rightarrow NH_3 + OH^- + K^+$ (*or* $\rightarrow NH_4OH + OH^- + K^+$)

g) a strip of magnesium metal is heated strongly in pure nitrogen gas.

$Mg + N_2 \rightarrow Mg_3N_2$

h) a solution of nickel chloride is added to a solution of sodium sulfide.

$Ni^{2+} + S^{2-} \rightarrow NiS$ (*or* $Ni^{2+} + H_2S \rightarrow NiS + H^+$; *or* $Ni^{2+} + HS^- \rightarrow NiS + H^+$)

1998 C

a) Solutions of tin(II) chloride and iron(III) chloride are mixed.

$Sn^{2+} + Fe^{3+} \rightarrow Sn^{4+} + Fe^{2+}$

b) Solutions of cobalt(II) nitrate and sodium hydroxide are mixed.

$Co^{2+} + OH^- \rightarrow Co(OH)_2$

c) Ethene gas is burned in air.

$C_2H_4 + O_2 \rightarrow CO_2 + H_2O$

d) Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed.

$H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$

e) Solid calcium sulfite is heated in a vacuum.

$CaSO_3 \rightarrow CaO + SO_2$

f) Excess hydrochloric acid is added to a solution of diamminesilver(I) nitrate.

$H^+ + Cl^- + Ag(NH_3)_2^+ \rightarrow AgCl + NH_4^+$

g) Solid sodium oxide is added to distilled water.

$Na_2O + H_2O \rightarrow Na^+ + OH^-$

h) A strip of zinc is added to a solution of 6.0-molar hydrobromic acid.

$Zn + H^+ \rightarrow Zn^{2+} + H_2$

2000 C

(a) A small piece of calcium metal is added to hot distilled water.

$Ca + H_2O \rightarrow H_2 + Ca(OH)_2$ $[Ca^{2+} + OH^-]$??

(b) Butanol is burned in air.

$C_4H_9OH + O_2 \rightarrow H_2O + CO_2$

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

$Ni^{2+} + NH_3 \rightarrow Ni[NH_3]_6^{2+}$

(d) A solution of copper(II) chloride is added to a solution of sodium sulfide.

$Cu^{2+} + S^{2-} \rightarrow CuS$

(e) A solution of tin(II) nitrate is added to a solution of silver nitrate.

$Sn^{2+} + Ag^{+} \rightarrow Ag + Sn^{4+}$

(f) Excess hydrobromic acid solution is added to a solution of potassium hydrogen carbonate.

$H^{+} + HCO_3^{-} \rightarrow H_2O + CO_2$

(g) Powdered strontium oxide is added to distilled water.

$SrO + H_2O \rightarrow Sr(OH)_2$

(h) Carbon monoxide gas is passed over hot iron(III) oxide.

$CO + Fe_2O_3 \rightarrow Fe + CO_2$

2001 C

(a) Sulfur dioxide gas is bubbled into distilled water.

$SO_2 + H_2O \rightarrow H_2SO_3$

(b) A drop of potassium thiocyanate solution is added to a solution of iron(III) nitrate.

$SCN^{-} + Fe^{3+} \rightarrow FeSCN^{2+}$

(c) A piece of copper wire is placed in a solution of silver nitrate.

$Cu + Ag^{+} \rightarrow Cu^{2+} + Ag$

(d) Solutions of potassium hydroxide and propanoic acid are mixed.

$OH^{-} + C_2H_5COOH \rightarrow C_2H_5COO^{-} + H_2O$

(e) A solution of iron(II) chloride is added to an acidified solution of sodium dichromate.

$Fe^{2+} + Cr_2O_7^{2-} + H^{+} \rightarrow Cr^{3+} + Fe^{3+} + H_2O$

(f) Chlorine gas is bubbled through a solution of potassium bromide.

$Cl_2 + Br^{-} \rightarrow Cl^{-} + Br_2$

(g) Solutions of strontium nitrate and sodium sulfate are mixed.

$Sr^{2+} + SO_4^{2-} \rightarrow SrSO_4$

(h) Powdered magnesium carbonate is heated strongly.

$MgCO_3 \rightarrow MgO + CO_2$

2002 C

(a) A solution of sodium iodide is added to a solution of lead(II) acetate.

$I^{-} + Pb^{2+} \rightarrow PbI_2$

(b) Pure solid phosphorus (white form) is burned in air.

$P_4 + O_2 \rightarrow P_4O_{10}$

(c) Solid cesium oxide is added to water.

$Cs_2O + H_2O \rightarrow Cs^{+} + OH^{-}$

(d) Excess concentrated hydrochloric acid is added to a 1.0 *M* solution of cobalt(II) chloride.

$Cl^{-} + Co^{3+} \rightarrow [CoCl_4]^{2-}$

(e) Solid sodium hydrogen carbonate (sodium bicarbonate) is strongly heated.

$NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

(f) An excess of hydrochloric acid is added to solid zinc sulfide.

$H^+ + ZnS \rightarrow H_2S + Zn^{2+}$

(g) Acidified solutions of potassium permanganate and iron(II) nitrate are mixed together.

$H^+ + MnO_4^- + Fe^{2+} \rightarrow H_2O + Mn^{2+} + Fe^{3+}$

(h) A solution of potassium hydroxide is added to solid ammonium chloride.

$OH^- + NH_4Cl \rightarrow NH_3 + H_2O + Cl^-$

2003 C

(a) A solution of potassium phosphate is mixed with a solution of calcium acetate.

$PO_4^{3-} + Ca^{2+} \rightarrow Ca_3(PO_4)_2$

(b) Solid zinc carbonate is added to 1.0 *M* sulfuric acid.

$ZnCO_3 + H^+ \rightarrow Zn^{2+} + H_2O + CO_2$

(c) A solution of hydrogen peroxide is exposed to strong sunlight.

$H_2O_2 \rightarrow H_2O + O_2$

(d) A 0.02 M hydrochloric acid solution is mixed with an equal volume of 0.01 *M* calcium hydroxide.

$OH^- + H^+ \rightarrow H_2O$

(e) Excess concentrated aqueous ammonia is added to solid silver chloride.

$NH_3 + AgCl \rightarrow [Ag(NH_3)_2]^+ + Cl^-$

(f) Magnesium ribbon is burned in oxygen.

$Mg + O_2 \rightarrow MgO$

(g) A bar of strontium metal is immersed in a 1.0 *M* copper(II) nitrate solution.

$Sr + Cu^{2+} \rightarrow Cu + Sr^{2+}$

(h) Solid dinitrogen pentoxide is added to water.

$N_2O_5 + H_2O \rightarrow H^+ + NO_3^-$

2004 C

(a) A solution of copper(II) sulfate is spilled onto a sheet of freshly polished aluminum metal.

$Al + Cu^{2+} \rightarrow Cu + Al^{3+}$

(b) Dimethyl ether is burned in air.

$(CH_3)_2O + O_2 \rightarrow H_2O + CO_2$

(c) A 0.1 *M* nitrous acid solution is added to the same volume of a 0.1 *M* sodium hydroxide solution.

$HNO_2 + OH^- \rightarrow H_2O + NO_2^-$

(d) Hydrogen iodide gas is bubbled into a solution of lithium carbonate.

$HI + CO_3^{2-} \rightarrow H_2O + CO_2 + I^-$

(e) An acidic solution of potassium dichromate is added to a solution of iron(II) nitrate.

$H^+ + Cr_2O_7^{2-} + Fe^{2+} \rightarrow H_2O + Cr^{3+} + Fe^{3+}$

(f) Excess concentrated aqueous ammonia is added to a solution of nickel(II) bromide.

$NH_3 + Ni^{2+} \rightarrow [Ni(NH_3)_4]^{2+}$

(g) A solution of sodium phosphate is added to a solution of aluminum nitrate.

$PO_4^{3-} + Al^{3+} \rightarrow AlPO_4$

(h) Concentrated hydrochloric acid is added to a solution of sodium sulfide.

$H^+ + HS^- \rightarrow H_2S$ **OR** $H^+ + S^{2-} \rightarrow H_2S$

2005 C

(a) A strip of zinc is placed in a solution of nickel(II) nitrate.

$Zn + Ni^{2+} \rightarrow Ni + Zn^{2+}$

(b) Solid aluminum hydroxide is added to a concentrated solution of potassium hydroxide.

$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$ ***OR*** $Al(OH)_6^{3-}$

(c) Ethyne (acetylene) is burned in air.

$C_2H_2 + O_2 \rightarrow H_2O + CO_2$

(d) Solid calcium carbonate is added to a solution of ethanoic (acetic) acid.

$CaCO_3 + CH_3COOH \rightarrow H_2O + CO_2 + Ca^{2+} + CH_3COO^-$

(e) Lithium metal is strongly heated in nitrogen gas.

$Li + N_2 \rightarrow Li_3N$

(f) Boron trifluoride gas is added to ammonia gas.

$BF_3 + NH_3 \rightarrow BF_3NH_3$

(g) Sulfur trioxide gas is bubbled into a solution of sodium hydroxide.

$SO_3 + OH^- \rightarrow H_2O + SO_4^{2-}$

(h) Equal volumes of 0.1 *M* solutions of lead(II) nitrate and magnesium iodide are combined.

$Pb^{2+} + I^- \rightarrow PbI_2$

2006 C

(a) Solid potassium chlorate is strongly heated.

$KClO_3 \rightarrow KCl + O_2$

(b) Solid silver chloride is added to a solution of concentrated hydrochloric acid.

$AgCl + Cl^- \rightarrow [AgCl_2]^-$

(c) A solution of ethanoic (acetic) acid is added to a solution of barium hydroxide.

$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

(d) Ammonia gas is bubbled into a solution of hydrofluoric acid.

$NH_3 + HF \rightarrow NH_4^+ + F^-$

(e) Zinc metal is placed in a solution of copper(II) sulfate.

$Zn + Cu^{2+} \rightarrow Cu + Zn^{2+}$

(f) Hydrogen phosphide (phosphine) gas is added to boron trichloride gas.

$H_3P + BCl_3 \rightarrow H_3PBCl_3$

(g) A solution of nickel(II) bromide is added to a solution of potassium hydroxide.

$Ni^{2+} + OH^- \rightarrow Ni(OH)_2$

(h) Hexane is combusted in air.

$C_6H_{14} + O_2 \rightarrow CO_2 + H_2O$