

Equations

page 1

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) $\text{PbCrO}_4(s) + \text{Na}^+ + \text{OH}^- \rightarrow \text{Pb}(\text{ONa})_2 + \text{Na}_2\text{CrO}_4 + \text{H}_2\text{O}$ [or $\text{PbO}_2 + \text{Cr}^{3+} \rightarrow \text{Pb}(\text{OH})_2$]
- b) $\text{LiH}(s) + \text{H}_2\text{O} \rightarrow \text{Li}^+ + \text{OH}^- + \text{H}_2$
- c) $\text{Zn}^{2+} + \text{SO}_4^{2-} + \text{NH}_3(\text{excess}) \rightarrow \text{Zn}(\text{NH}_3)_2^{2+}$
- d) $\text{Na}^+ + \text{CH}_3\text{COO}^- + \text{H}^+(\text{excess}) + \text{Cl}^- \rightarrow \text{CH}_3\text{COOH}$
- e) $\text{K}^+ + \text{Cr}_2\text{O}_7^{2-} + \text{H}^+ + \text{SO}_4^{2-} + \text{Na}^+ + \text{I}^- \rightarrow \text{Cr}^{3+} + \text{I}_2 + \text{H}_2\text{O}$
- f) $\text{BaCO}_3(s) + \text{H}^+(\text{excess}) + \text{NO}_3^- \rightarrow \text{Ba}^{2+} + \text{H}_2\text{O} + \text{CO}_2$
- g) $\text{Al}_2\text{S}_3(s) + \text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + \text{H}_2\text{S}$
- h) $\text{Ag}(s) + \text{H}^+ + \text{NO}_3^- \rightarrow$ [nitric acid is 6M] $\text{Ag}^+ + \text{NO}(g) + \text{H}_2\text{O}$

1965

- a) $\text{Zn}(s) + \text{Sn}^{2+} \rightarrow \text{Sn}(s) + \text{Zn}^{2+}$
- b) $\text{Na}^+ + \text{Cr}_2\text{O}_7^{2-} + \text{Fe}^{2+} + \text{SO}_4^{2-} + \text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{Fe}^{3+} + \text{Cr}^{3+} + \text{H}_2\text{O}$
- c) $\text{TiCl}_4(l) + \text{H}_2\text{O}(l) \rightarrow \text{Ti}(\text{OH})_4(s) + \text{H}^+(aq) + \text{Cl}^-(aq)$
- d) $\text{NH}_4\text{Cl}(s) + \text{Na}^+ + \text{OH}^- \rightarrow \text{NH}_3(g) \text{ or } (aq) + \text{Cl}^-$
- e) $\text{NaHCO}_3(s) + \text{Na}^+ + \text{OH}^- \rightarrow \text{Na}^+ + \text{CO}_3^{2-}(aq) + \text{H}_2\text{O}$
- f) $\text{CaSO}_3(s) + \text{H}_3\text{O}^+ + \text{Cl}^- \rightarrow \text{Ca}^{2+} + \text{SO}_2(g) + \text{H}_2\text{O}$
- g) $\text{Na}(s) + \text{NH}_3(l) \text{ (non-aqueous)} \rightarrow \text{Na}^+ + \text{NH}_2^- + \text{H}_2$
- h) $\text{CH}_3\text{COOH}(l) + \text{CH}_3\text{OH}(l) \text{ (non-aqueous)} \rightarrow \text{CH}_3\text{COOCH}_3 + \text{H}_2\text{O}$

1966

- a) $\text{IO}_3^- + \text{I}^- + \text{H}_3\text{O}^+ \rightarrow \text{I}_2 + \text{H}_2\text{O}$
- b) $\text{Ca}_3(\text{PO}_4)_2(s) + \text{H}_3\text{O}^+ + \text{Cl}^- \text{ (excess acid)} \rightarrow \text{H}_3\text{PO}_4 + \text{Ca}^{2+} + \text{H}_2\text{O}$
- c) $\text{NaNH}_2(s) + \text{H}_2\text{O} \rightarrow \text{Na}^+(aq) + \text{NH}_3(aq) + \text{OH}^-(aq)$
- d) $\text{Zn}(s) + \text{H}_3\text{O}^+ + \text{Cl}^- \rightarrow \text{Zn}^{2+} + \text{H}_2(g) + \text{H}_2\text{O}$

- e) $\text{Cr}_2\text{O}_7^{2-} + \text{OH}^- \rightarrow \text{CrO}_4^{2-} + \text{H}_2\text{O}$
- f) $\text{BaCO}_3(s) + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Ba}^{2+} + \text{HCO}_3^-(aq)$
- g) $\text{MnO}_4^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{MnO}_4^- + \text{Mn}^{2+} + \text{H}_2\text{O}$
- h) $\text{Zn}(\text{OH})_2(s) + \text{NH}_3(aq) \rightarrow \text{Zn}(\text{NH}_3)_4^{2+} + \text{OH}^-$

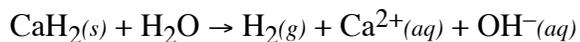
1967

- a) $\text{PbCl}_2(s) \text{ (moist)} + \text{H}_2\text{S}(g) \rightarrow \text{PbS}(s) + \text{H}^+(aq) + \text{Cl}^-(aq)$
- b) $\text{NaOH}(s) \text{ (moist)} + \text{CO}_2(g) \rightarrow \text{Na}^+(aq) + \text{HCO}_3^-(aq)$
- c) $\text{AgCl}(s) + \text{NH}_3(aq) \rightarrow \text{Ag}(\text{NH}_3)_2^+(aq) + \text{Cl}^-(aq)$
- d) $\text{MnO}_4^-(aq) + \text{H}^+(aq) + \text{I}^-(aq) \rightarrow \text{Mn}^{2+}(aq) + \text{H}_2\text{O} + \text{I}_2$
- e) $\text{PCl}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3(aq) + \text{H}^+(aq) + \text{Cl}^-(aq)$
- f) $\text{H}_2\text{O}_2(aq) \text{ (heated)} \rightarrow \text{H}_2\text{O} + \text{O}_2(g)$
- g) $\text{Hg}(l) + \text{HNO}_3(\text{conc}) \rightarrow \text{Hg}^{2+}(aq) + \text{H}_2\text{O} + \text{NO}_2(g)$
- h) $\text{BF}_3(g) + (\text{CH}_3)_3\text{N}(g) \rightarrow (\text{CH}_3)_3\text{NBF}_3$ {Lewis Acid-Base reaction}

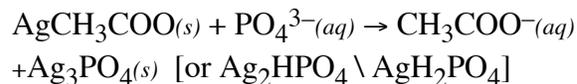
1968

- a) iron(III) ions are reduced by iodide ions.
 $\text{Fe}^{3+}(aq) + \text{I}^-(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{I}_2$ [or $\text{I}_3^-(aq)$]
- b) hydrogen sulfide is bubbled through a solution of silver nitrate.
 $\text{H}_2\text{S}(aq) + \text{Ag}^+(aq) \rightarrow \text{Ag}_2\text{S}(s) + \text{H}^+(aq)$
- c) potassium permanganate solution is added to concentrated hydrochloric acid.
 $\text{MnO}_4^-(aq) + \text{H}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{Mn}^{2+}(aq) + \text{Cl}_2(g) + \text{H}_2\text{O}$
- d) concentrated (15M) ammonia solution is added in excess to a solution of copper(II) nitrate.
 $\text{NH}_3(aq) + \text{Cu}^{2+}(aq) \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}(aq)$
- 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.
 $\text{Mg}(s) + \text{NO}_3^-(aq) + \text{H}^+(aq) \rightarrow \text{Mg}^{2+}(aq) + \text{NH}_4^+(aq)$
- f) excess water is added to solid calcium hydride.

Equations



- g) excess silver acetate is added to a solution of trisodium phosphate.

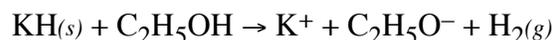


- h) solid sodium cyanide is added to water.



1969

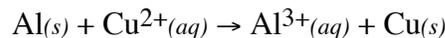
- a) solid potassium hydride is added to anhydrous ethyl alcohol.



- b) lithium metal is burned in air.



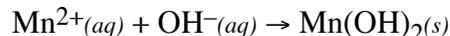
- c) aluminum metal is added to a solution of copper(II) chloride.



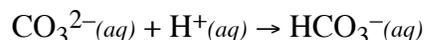
- d) liquid phosphorus trichloride is poured into a large excess of water.



- e) manganese(II) nitrate solution is mixed with sodium hydroxide solution.



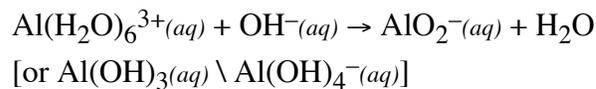
- f) equal volumes of dilute equimolar solutions of sodium carbonate and hydrochloric acid are mixed.



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

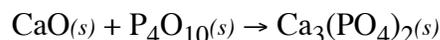


- h) an excess of sodium hydroxide solution is added to a solution of aluminum chloride.



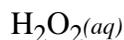
1970

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



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

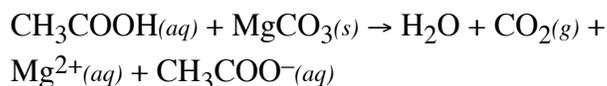




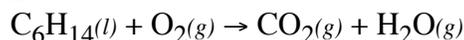
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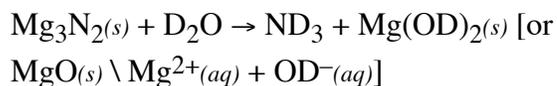
- c) dilute acetic acid solution is added to solid magnesium carbonate.



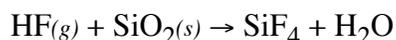
- d) the hydrocarbon hexane is burned in excess oxygen.



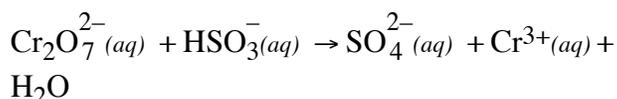
- e) solid magnesium nitride is added to excess deuterium oxide.



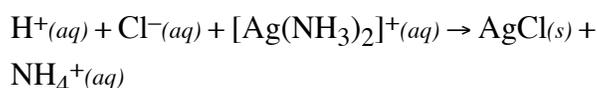
- f) gaseous hydrofluoric acid reacts with solid silicon dioxide



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

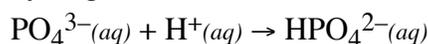


- h) dilute hydrochloric acid is added to a solution of diamminesilver(I) nitrate

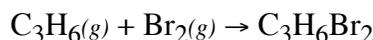


1971

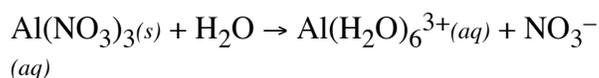
- a) equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.



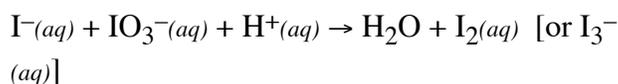
- b) propene gas is mixed with bromine vapor.



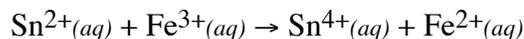
- c) solid aluminum nitrate is dissolved in water.



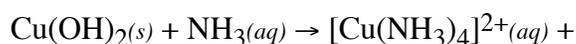
- d) solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.



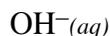
- e) a solution of tin(II) sulfate is added to a solution of iron(III) sulfate.



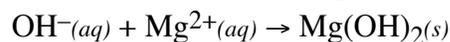
- f) a suspension of copper(II) hydroxide is treated with an excess of ammonia water.



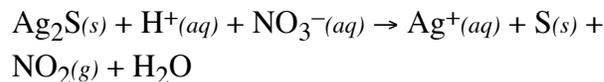
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- g) a saturated solution of calcium hydroxide is added to a solution of magnesium chloride.

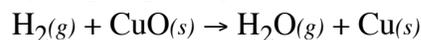


- h) solid silver sulfide is warmed with dilute nitric acid.

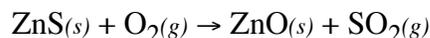


1972

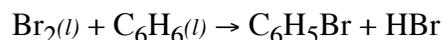
- a) hydrogen gas is passed over hot copper(II) oxide.



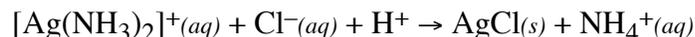
- b) solid zinc sulfide is heated in an excess of oxygen.



- c) a limited amount of liquid bromine is added to an excess of benzene.



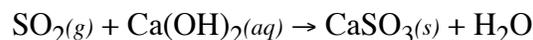
- d) a solution of diamminesilver(I) chloride is treated with dilute nitric acid.



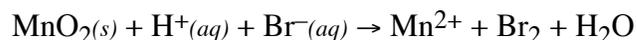
- e) metallic copper is heated with concentrated sulfuric acid.



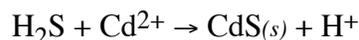
- f) sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.



- g) manganese(IV) oxide is added to warm, concentrated hydrobromic acid.



- h) hydrogen sulfide gas is added to a solution of cadmium nitrate.

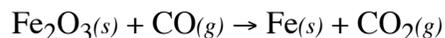


1973

- a) chlorine gas is bubbled into cold dilute sodium hydroxide.



- b) solid iron(III) oxide is heated in excess carbon monoxide.

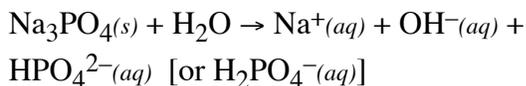


- c) solid magnesium carbonate is heated.



Equations

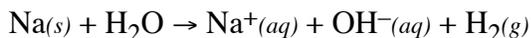
- d) trisodium phosphate crystals are added to water.



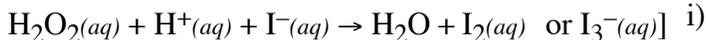
- e) gaseous diborane, B_2H_6 , is burned in excess oxygen.



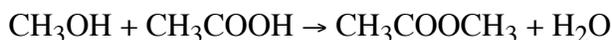
- f) small chunks of solid sodium are added to water.



- g) hydrogen peroxide solution is added to acidified potassium iodide solution.



- h) pure methyl alcohol and pure acetic acid are mixed.

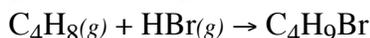


- i) an excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.



1974

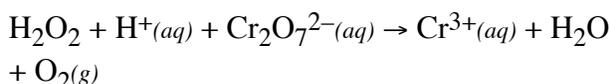
- a) a sample of pure 2-butene is treated with hydrogen bromide gas.



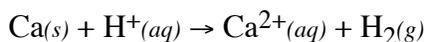
- b) water is added to a sample of pure phosphorus tribromide.



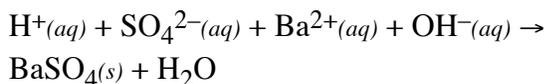
- c) hydrogen peroxide is added to an acidified solution of potassium dichromate.



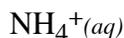
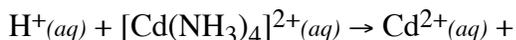
- d) calcium metal is added to a dilute solution of hydrochloric acid.



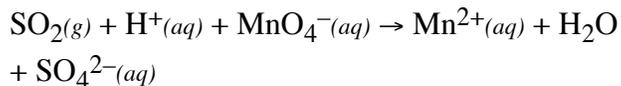
- e) a solution of sulfuric acid is added to a solution of barium hydroxide until the same number of moles of each compound has been added.



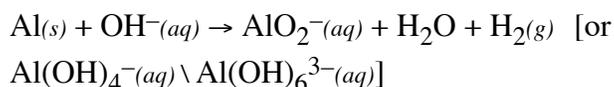
- f) excess dilute nitric acid is added containing the tetraamminecadmium(II) ion.



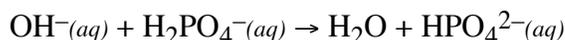
- g) sulfur dioxide gas is bubbled through an acidified solution of potassium permanganate.



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

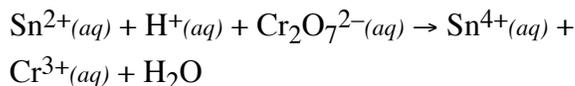


- i) a solution of sodium hydroxide is added to a solution of sodium dihydrogen phosphate until the same number of moles of each compound had been added.

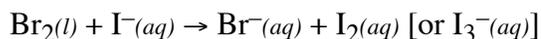


1975

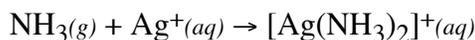
- a) a solution containing tin(II) ions is added to an acidified solution of potassium dichromate.



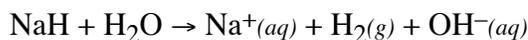
- b) liquid bromine is added to a solution of potassium iodide.



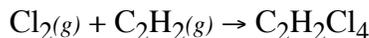
- c) an excess of ammonia gas is bubbled through a solution saturated with silver chloride.



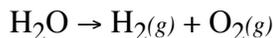
- d) water is added to a sample of pure sodium hydride.



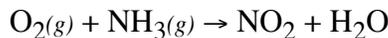
- e) an excess of chlorine gas is added to pure acetylene.



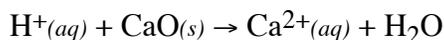
- f) a dilute solution of sulfuric acid is electrolyzed between platinum electrodes.



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



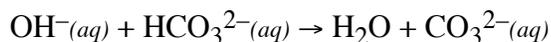
- h) dilute nitric acid is added to crystals of pure calcium oxide.



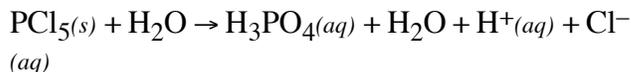
Equations

page 6

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

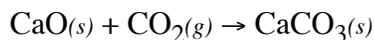


- c) solid phosphorus pentachloride is added to excess water.



1976

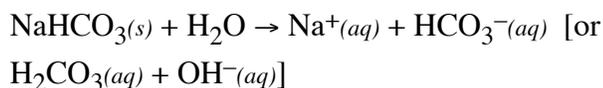
- a) solid calcium oxide is exposed to a stream of carbon dioxide gas.



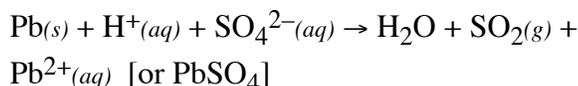
- b) dinitrogen trioxide gas is bubbled into water.



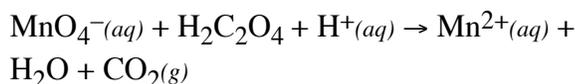
- c) sodium hydrogen carbonate is dissolved in water.



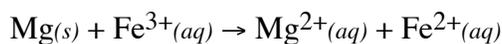
- d) pellets of lead are dropped into hot sulfuric acid.



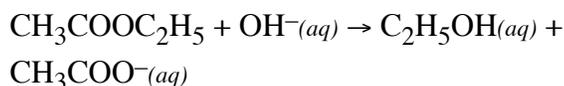
- e) potassium permanganate solution is added to a solution of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, acidified with a few drops of sulfuric acid.



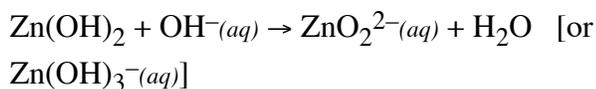
- f) magnesium turnings are added to a solution of iron(III) chloride.



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

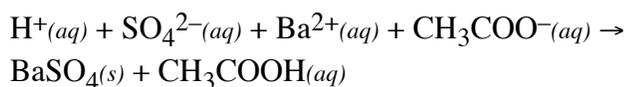


- h) a suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.



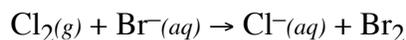
1977

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

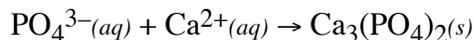


Equations

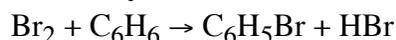
- f) chlorine gas is bubbled into a solution of sodium bromide. $\text{H}_2\text{S}(g) + \text{OH}^-(aq) \rightarrow \text{S}^{2-}(aq) + \text{H}_2\text{O}$



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

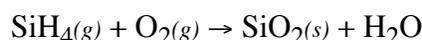


- h) benzene is treated with bromine in the presence of a catalyst.

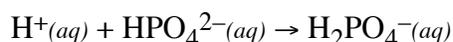


1978

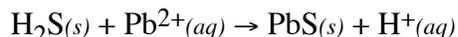
- a) gaseous silane, SiH_4 , is burned in oxygen.



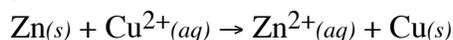
- b) equal volumes of 0.1M hydrochloric acid and 0.1M sodium monohydrogen phosphate are mixed.



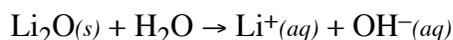
- c) hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.



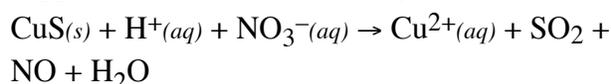
- d) solid zinc strips are added to a solution of copper(II) sulfate.



- e) solid lithium oxide is added to excess water.



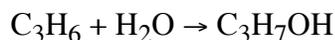
- f) copper(II) sulfide is oxidized by dilute nitric acid



- g) silver chloride is dissolved in excess ammonia solution.



- h) propene reacts with water in the presence of a catalyst.



1979

- a) a solution of copper(II) sulfate is electrolyzed using inert electrodes.



- b) hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.

Equations

- c) solutions of silver nitrate and sodium chromate are mixed.
 $\text{Ag}^+(aq) + \text{CrO}_4^{2-}(aq) \rightarrow \text{Ag}_2\text{CrO}_4(s)$
- d) sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.
 $\text{Al}(\text{OH})_3(s) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O} + \text{AlO}_2^-(aq)$ [or $\text{Al}(\text{OH})_4^-$]
- e) solid sodium sulfite is added to water.
 $\text{Na}_2\text{SO}_3(s) + \text{H}_2\text{O} \rightarrow \text{Na}^+(aq) + \text{HSO}_3^-(aq) + \text{OH}^-(aq)$
- f) a solution of formic acid, HCOOH, is oxidized by an acidified solution of potassium dichromate.
 $\text{HCOOH}(aq) + \text{H}^+(aq) + \text{Cr}_2\text{O}_7^{2-}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O} + \text{Cr}^{3+}(aq)$
- g) ammonia gas and carbon dioxide gas are bubbled into water.
 $\text{NH}_3(g) + \text{CO}_2(g) + \text{H}_2\text{O} \rightarrow \{\text{NH}_4\text{OH} + \text{H}_2\text{CO}_3\}$
 $\rightarrow \text{NH}_4^+(aq) + \text{CO}_3^{2-}(aq)$
- h) concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.
 $\text{HCl} + \text{MnO}_2 \rightarrow \text{Cl}_2(g) + \text{Mn}^{2+}(aq) + \text{H}_2\text{O}$
- f) chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.
 $\text{Cl}_2(g) + \text{OH}^-(aq) \rightarrow \text{ClO}^-(aq) + \text{Cl}^-(aq) + \text{H}_2\text{O}$

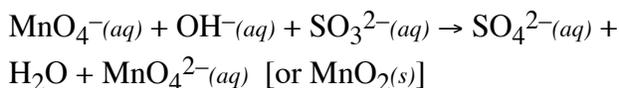
1980

- a) solutions of sodium fluoride and dilute hydrochloric acid are mixed.
 $\text{F}^-(aq) + \text{H}^+(aq) \rightarrow \text{HF}(aq)$
- b) a saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.
 $\text{Ba}^{2+}(aq) + \text{OH}^-(aq) + \text{Fe}^{3+}(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{BaSO}_4(s) + \text{Fe}(\text{OH})_3(s)$
- c) a solution of ammonium sulfate is added to a potassium hydroxide solution.
 $\text{NH}_4^+(aq) + \text{OH}^-(aq) \rightarrow \text{NH}_3(aq) + \text{H}_2\text{O}$
- d) carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.
 $\{\text{CO}_2 + \text{H}_2\text{O} / \text{H}_2\text{CO}_3\} \quad \text{H}_2\text{CO}_3 + \text{OH}^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$
- e) solid copper is added to a dilute nitric acid solution.
 $\text{Cu}(s) + \text{H}^+(aq) + \text{NO}_3^-(aq) \rightarrow \text{Cu}^{2+}(aq) + \text{H}_2\text{O} +$

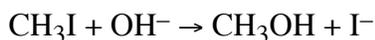
Equations

page 9

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

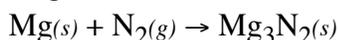


- h) methyl iodide is heated with a solution of sodium hydroxide.



1981

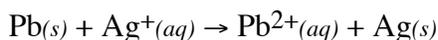
- a) magnesium metal is burned in nitrogen gas.



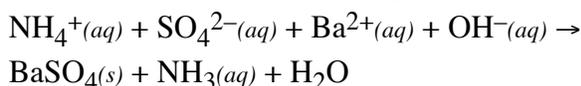
- b) sulfur dioxide gas is passed over solid calcium oxide.



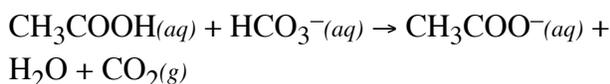
- c) lead foil is immersed in silver nitrate solution.



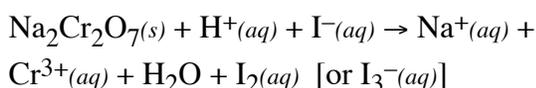
- d) a solution of ammonium sulfate is added to a saturated solution of barium hydroxide.



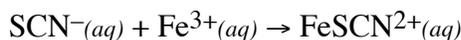
- e) acetic acid solution is added to a solution of sodium hydrogen carbonate.



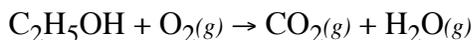
- f) solid sodium dichromate is added to an acidified solution of sodium iodide.



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

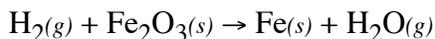


- h) ethanol is completely burned in air.

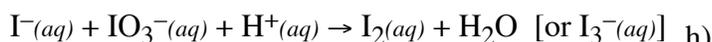


1982

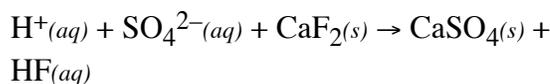
- a) hydrogen gas is passed over hot iron(III) oxide.



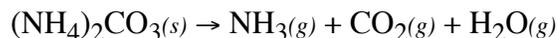
- b) solutions of potassium iodide and potassium iodate are mixed in acid solution.



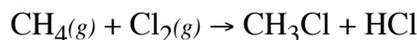
- c) dilute sulfuric acid is added to solid calcium fluoride.



- d) solid ammonium carbonate is heated.



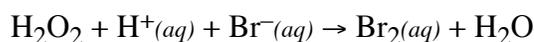
- e) methane gas is heated with an excess of chlorine gas.



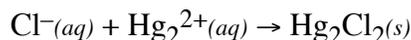
- f) a concentrated solution of ammonia is added to a suspension of zinc hydroxide.



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

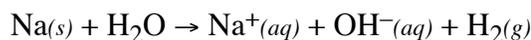


- h) dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.

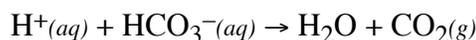


1985

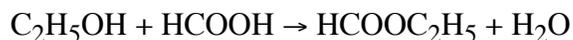
- a) sodium metal is added to water.



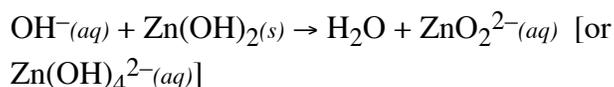
- b) dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.



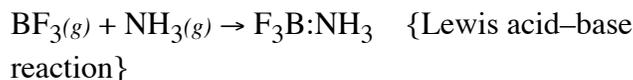
- c) ethanol and formic acid (methanoic acid) are mixed and warmed.



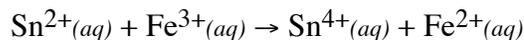
- d) excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.



- e) the gases boron trifluoride and ammonia are mixed.



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

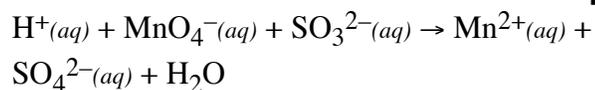


- g) phosphorus(V) oxytrichloride is added to water.



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

Equations



1986

- a) a piece of lithium metal is dropped into a container of nitrogen gas.
 $\text{Li}(\text{s}) + \text{N}_2(\text{g}) \rightarrow \text{Li}_3\text{N}$
- b) dilute hydrochloric acid is added to a solution of potassium sulfite.
 $\text{H}^+(\text{aq}) + \text{SO}_3^{2-}(\text{aq}) \rightarrow \text{HSO}_3^-(\text{aq})$
- c) solid sodium oxide is added to water.
 $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O} \rightarrow \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$
- d) a solution of sodium sulfide is added to a solution of zinc nitrate.
 $\text{S}^{2-}(\text{aq}) + \text{Zn}^{2+}(\text{aq}) \rightarrow \text{ZnS}(\text{s})$
- e) a solution of ammonia is added to a dilute solution of acetic acid.
 $\text{NH}_3(\text{aq}) + \text{CH}_3\text{COOH}(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$
- f) a piece of iron is added to a solution of iron(III) sulfate.
 $\text{Fe}(\text{s}) + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq})$
- g) ethene (ethylene) gas is bubbled through a solution of bromine.
 $\text{C}_2\text{H}_4(\text{g}) + \text{Br}_2 \rightarrow \text{C}_2\text{H}_4\text{Br}_2$
- h) chlorine gas is bubbled into a solution of potassium iodide.
 $\text{Cl}_2(\text{g}) + \text{I}^-(\text{aq}) \rightarrow \text{Cl}^-(\text{aq}) + \text{I}_2(\text{aq})$ [or $\text{I}_3^-(\text{aq})$]

1987

- a) solid calcium is added to warm water.
 $\text{Ca}(\text{s}) + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$
- b) powdered magnesium oxide is added to a container of carbon dioxide gas.
 $\text{MgO}(\text{s}) + \text{CO}_2(\text{g}) \rightarrow \text{MgCO}_3(\text{s})$
- c) gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.
 $\text{H}_2\text{S}(\text{g}) + \text{Ni}^{2+}(\text{aq}) \rightarrow \text{NiS}(\text{s}) + \text{H}^+(\text{aq})$
- d) excess concentrated sodium hydroxide solution is added to solid aluminum hydroxide.
 $\text{OH}^-(\text{aq}) + \text{Al}(\text{OH})_3(\text{s}) \rightarrow \text{H}^+(\text{aq}) + \text{AlO}_2^-(\text{aq})$ [or $\text{Al}(\text{OH})_4^- \setminus \text{Al}(\text{OH})_6^{3-} \setminus \text{Al}(\text{OH})_4(\text{H}_2\text{O})_2^-$]
- e) solid silver is added to a dilute nitric acid (6M) solution.

Equations

page 11

- $\text{Ag}(s) + \text{H}^+(aq) + \text{NO}_3^-(aq) \rightarrow \text{Ag}^+(aq) + \text{NO}(g) + \text{H}_2\text{O}$ f) excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.
 $\text{OH}^-(aq) + \text{H}_2\text{PO}_4^-(aq) \rightarrow \text{PO}_4^{3-}(aq) + \text{H}_2\text{O}$
- g) hydrogen peroxide solution is added to a solution of iron(II) sulfate.
 $\text{H}_2\text{O}_2(aq) + \text{Fe}^{2+}(aq) \rightarrow \text{H}_2\text{O} + \text{Fe}^{3+}(aq)$ [or $\text{Fe}(\text{OH})_3(s)$]
- h) propanol is burned completely in air.
 $\text{C}_3\text{H}_7\text{OH}(l) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g)$

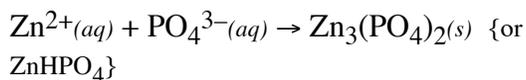
1988

- a) a solution of potassium iodide is added to an acidified solution of potassium dichromate.
 $\text{H}^+(aq) + \text{I}^-(aq) + \text{Cr}_2\text{O}_7^{2-}(aq) \rightarrow \text{I}_2(aq) + \text{Cr}^{3+}(aq) + \text{H}_2\text{O}$ (any reasonable I^- oxidation prod. accepted)
- b) a solution of sodium hydroxide is added to a solution of ammonium chloride.
 $\text{OH}^-(aq) + \text{NH}_4^+(aq) \rightarrow \text{H}_2\text{O} + \text{NH}_3(aq)$ [or $\text{NH}_4\text{OH}(aq)$]
- c) a strip of magnesium is added to a solution of silver nitrate.
 $\text{Mg}(s) + \text{Ag}^+(aq) \rightarrow \text{Mg}^{2+}(aq) + \text{Ag}(s)$
- d) solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst.
 $\text{KClO}_3(s) \rightarrow \text{KCl}(s) + \text{O}_2(g)$ (MnO_2 over arrow)
- e) dilute hydrochloric acid is added to a solution of potassium carbonate.
 $\text{H}^+(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}$ (or $\text{H}_2\text{CO}_3(aq)$ or $\text{HCO}_3^-(aq)$)
- f) sulfur trioxide gas is added to excess water.
 $\text{SO}_3(g) + \text{H}_2\text{O} \rightarrow \text{H}^+(aq) + \text{HSO}_4^-(aq)$ {or $\text{H}^+(aq) + \text{SO}_4^{2-}(aq)$ }
- g) dilute sulfuric acid is added to a solution of barium chloride.
 $\text{SO}_4^{2-}(aq) + \text{Ba}^{2+}(aq) \rightarrow \text{BaSO}_4(s)$ [or $\text{HSO}_4^-(aq) + \text{Ba}^{2+}(aq) \rightarrow \text{BaSO}_4(s) + \text{H}^+(aq)$]
- h) a concentrated solution of ammonia is added to a solution of copper(II) chloride.
 $\text{Cu}^{2+} + \text{NH}_3 \rightarrow \text{Cu}(\text{NH}_3)_4^{2+}$ {partial for $\text{Cu}(\text{OH})_2$ }

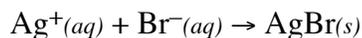
1989

Equations

- a) solutions of zinc sulfate and sodium phosphate are mixed.



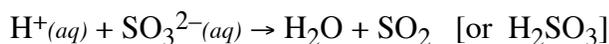
- b) solutions of silver nitrate and lithium bromide are mixed.



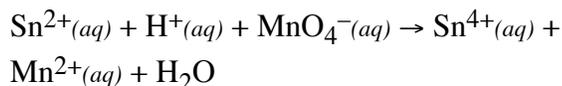
- c) a stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.



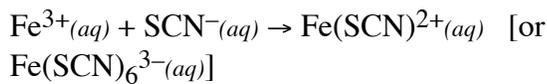
- d) excess hydrochloric acid solution is added to a solution of potassium sulfite.



- e) a solution of tin(II) chloride is added to an acidified solution of potassium permanganate.



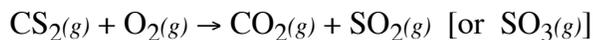
- f) a solution of ammonium thiocyanate is added to a solution of iron(III) chloride.



- g) samples of boron trichloride gas and ammonia gas are mixed.

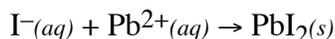


- h) carbon disulfide vapor is burned in excess oxygen.

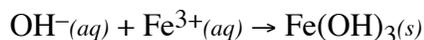


1990

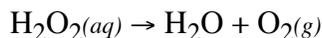
- a) solutions of sodium iodide and lead nitrate are mixed.



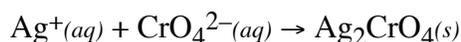
- b) a solution of ammonia is added to a solution of ferric chloride.



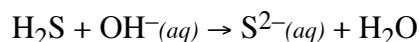
- c) a solution of hydrogen peroxide is heated.



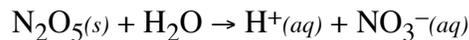
- d) solutions of silver nitrate and sodium chromate are mixed.



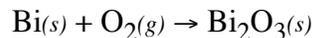
- e) hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.



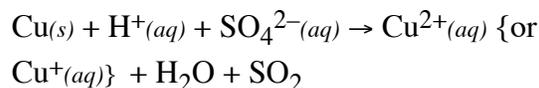
- f) solid dinitrogen pentoxide is added to water.



- g) a piece of solid bismuth is heated strongly in oxygen.

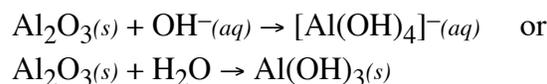


- h) a strip of copper metal is added to a concentrated solution of sulfuric acid.

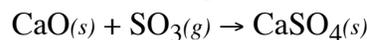


1991 C

- a) solid aluminum oxide is added to a solution of sodium hydroxide.



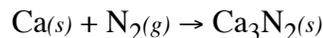
- b) solid calcium oxide is heated in the presence of sulfur trioxide gas.



- c) equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed.



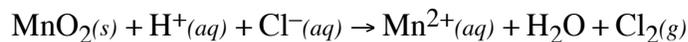
- d) calcium metal is heated strongly in nitrogen gas.



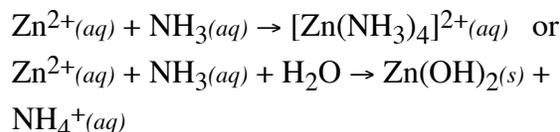
- e) solid copper(II) sulfide is heated strongly in oxygen gas.



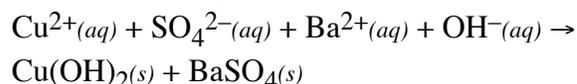
- f) a concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated.



- g) a concentrated solution of ammonia is added to a solution of zinc iodide.



- h) a solution of copper(II) sulfate is added to a solution of barium hydroxide.

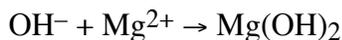


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1992 C

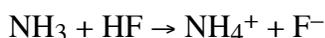
- a) an excess of sodium hydroxide solution is added to a solution of magnesium nitrate.



- b) solid lithium hydride is added to water.



- c) solutions of ammonia and hydrofluoric acid are mixed.



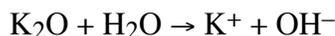
- d) a piece of aluminum metal is added to a solution of silver nitrate.



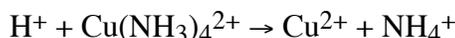
- e) a solution of potassium iodide is electrolyzed.



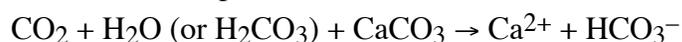
- f) solid potassium oxide is added to water.



- g) an excess of nitric acid solution is added to a solution of tetraamminecopper(II) sulfate.

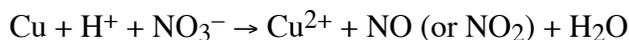


- h) carbon dioxide gas is bubbled through water contain a suspension of calcium carbonate.

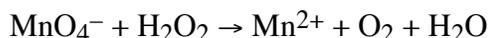


1993 C

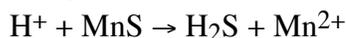
- a) A strip of copper is immersed in dilute nitric acid.



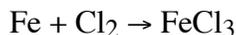
- b) Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.



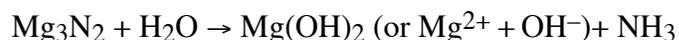
- c) Concentrated hydrochloric acid is added to solid manganese (II) sulfide.



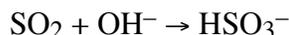
- d) Excess chlorine gas is passed over hot iron filings.



- e) Water is added to a sample of solid magnesium nitride.



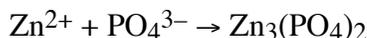
- f) Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.



- g) Excess concentrated ammonia solution is added to a suspension of silver chloride.



- h) Solution of tri-potassium phosphate and zinc nitrate are mixed.

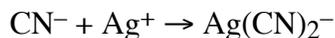


1994 C

- a) Excess sodium cyanide solution is added to a

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solution of silver nitrate.



- b) Solutions of manganese(II) sulfate and ammonium sulfide are mixed.
$$\text{Mn}^{2+} + \text{S}^{2-} \rightarrow \text{MnS}_{(s)}$$
- c) Phosphorus(V) oxide powder is sprinkled over distilled water.
$$\text{P}_4\text{O}_{10} \text{ (or } \text{P}_2\text{O}_5) + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4$$
- d) Solid ammonium carbonate is heated.
$$(\text{NH}_4)_2\text{CO}_3 \rightarrow \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O}$$
- e) Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide.
$$\text{CO}_2 + \text{OH}^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$$
- f) A concentrated solution of hydrochloric acid is added to solid potassium permanganate.
$$\text{KMnO}_4 + \text{H}^+ + \text{Cl}^- \rightarrow \text{Cl}_2 + \text{Mn}^{2+} + \text{H}_2\text{O} + \text{K}^+$$
- g) A small piece of sodium metal is added to distilled water.
$$\text{Na} + \text{H}_2\text{O} \rightarrow \text{Na}^+ + \text{OH}^- + \text{H}_2$$
- h) A solution of potassium dichromate is added to an acidified solution of iron(II) chloride.
$$\text{Cr}_2\text{O}_7^{2-} + \text{H}^+ + \text{Fe}^{2+} \rightarrow \text{Cr}^{3+} + \text{H}_2\text{O} + \text{Fe}^{3+}$$

1995 C

- a) Ethanol is burned in oxygen.
$$\text{C}_2\text{H}_5\text{OH} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$
- b) Solid barium oxide is added to distilled water.
$$\text{BaO} + \text{H}_2\text{O} \rightarrow \text{Ba}^{2+} + \text{OH}^-$$
- c) Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.
$$\text{Cl}_2 + \text{OH}^- \rightarrow \text{Cl}^- + \text{ClO}^- \text{ (or } \text{ClO}^-/\text{ClO}_2^-/\text{ClO}_3^-) + \text{H}_2\text{O}$$
- d) A solution of iron(II) nitrate is exposed to air for an extended period of time.
$$\text{Fe}^{2+} + \text{O}_2 \text{ (+ } \text{H}_2\text{O)} \rightarrow \text{Fe}_2\text{O}_3 \text{ or } \text{FeO}(\text{OH}) \text{ or } \text{Fe}(\text{OH})_3$$
- e) Excess concentrated sulfuric acid is added to solid calcium phosphate.
$$\text{H}^+ + \text{SO}_4^{2-} + \text{Ca}_3(\text{PO}_4)_2 \rightarrow \text{CaSO}_4 \text{ (or ions)} + \text{H}_3\text{PO}_4$$
- f) Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.
$$\text{H}_2\text{S} + \text{Hg}^{2+} \rightarrow \text{HgS} + \text{H}^+ \text{ or}$$

$$\text{H}_2\text{S} + \text{HgCl}_2 \rightarrow \text{HgS} + \text{H}^+ + \text{Cl}^-$$

Equations

- g) Solid calcium hydride is added to distilled water.
 $\text{CaH}_2 + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$ [or $\text{Ca}^{2+} + \text{OH}^-$] + H_2
- h) A bar of zinc metal is immersed in a solution of copper(II) sulfate.
 $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$
- d) phosphine (phosphorus trihydride) gas is bubbled into liquid boron trichloride.
 $\text{PH}_3 + \text{BCl}_3 \rightarrow \text{PH}_3\text{BCl}_3$

1996 C

- a) solid calcium carbonate is strongly heated.
 $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$
- b) a piece of nickel metal is immersed in a solution of copper(II) sulfate.
 $\text{Ni} + \text{Cu}^{2+} \rightarrow \text{Ni}^{2+} + \text{Cu}$
- c) equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed.
 $\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$
- d) chlorine gas is bubbled into a solution of sodium bromide.
 $\text{Cl}_2 + \text{Br}^- \rightarrow \text{Cl}^- + \text{Br}_2$
- e) ammonia gas is bubbled into a solution of ethanoic (acetic) acid.
 $\text{NH}_3 + \text{CH}_3\text{COOH} \rightarrow \text{NH}_4^+ + \text{CH}_3\text{COO}^-$
- f) solid ammonium carbonate is added to a saturated solution of barium hydroxide.
 $(\text{NH}_4)_2\text{CO}_3 + \text{Ba}^{2+} + \text{OH}^- \rightarrow \text{NH}_3 + \text{BaCO}_3 + \text{H}_2\text{O}$
- g) drops of liquid dinitrogen trioxide are added to distilled water.
 $\text{N}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow \text{HNO}_2$
- h) solutions of potassium permanganate and sodium oxalate are mixed.
 $\text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{MnO}_2 + \text{CO}_2$

1997 C

- a) excess potassium hydroxide solution is added to a solution of aluminum nitrate.
 $\text{OH}^- + \text{Al}^{3+} \rightarrow \text{Al(OH)}_3$ (or Al(OH)_4^- ;
 $\text{Al(OH)}_4(\text{H}_2\text{O})_2^-$; Al_2O_3 ; $\text{Al}_2\text{O}_3 \cdot x \text{H}_2\text{O}$; AlO_2^-)
- b) a solution of sodium bromide is added to an acidified solution of potassium bromate.
 $\text{Br}^- + \text{H}^+ + \text{BrO}_3^- \rightarrow \text{Br}_2 + \text{H}_2\text{O}$
- c) sulfur dioxide gas is bubbled into distilled water.
 $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$ (or $\rightarrow \text{H}^+ + \text{HSO}_3^-$; or \rightarrow

Equations

- e) hydrogen gas is passed over hot iron(II) oxide powder.
$$\text{H}_2 + \text{FeO} \rightarrow \text{Fe} + \text{H}_2\text{O}$$
- f) solid potassium amide is added to distilled water.
$$\text{KNH}_2 + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{OH}^- + \text{K}^+ \text{ (or } \rightarrow \text{NH}_4\text{OH} + \text{OH}^- + \text{K}^+)$$
- g) a strip of magnesium metal is heated strongly in pure nitrogen gas.
$$\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$$
- h) a solution of nickel chloride is added to a solution of sodium sulfide.
$$\text{Ni}^{2+} + \text{S}^{2-} \rightarrow \text{NiS} \text{ (or } \text{Ni}^{2+} + \text{H}_2\text{S} \rightarrow \text{NiS} + \text{H}^+;$$

$$\text{or } \text{Ni}^{2+} + \text{HS}^- \rightarrow \text{NiS} + \text{H}^+)$$
- b) Solid ammonium nitrate is heated to temperatures above 300°C.
$$\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + \text{O}_2 + \text{H}_2\text{O} \text{ (or } \text{N}_2\text{O} + \text{H}_2\text{O)}$$

1998 C

- a) Solutions of tin(II) chloride and iron(III) chloride are mixed.
$$\text{Sn}^{2+} + \text{Fe}^{3+} \rightarrow \text{Sn}^{4+} + \text{Fe}^{2+}$$
- b) Solutions of cobalt(II) nitrate and sodium hydroxide are mixed.
$$\text{Co}^{2+} + \text{OH}^- \rightarrow \text{Co(OH)}_2$$
- c) Ethene gas is burned in air.
$$\text{C}_2\text{H}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$
- d) Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed.
$$\text{H}_3\text{PO}_4 + \text{OH}^- \rightarrow \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}$$
- e) Solid calcium sulfite is heated in a vacuum.
$$\text{CaSO}_3 \rightarrow \text{CaO} + \text{SO}_2$$
- f) Excess hydrochloric acid is added to a solution of diamminesilver(I) nitrate.
$$\text{H}^+ + \text{Cl}^- + \text{Ag(NH}_3)_2^+ \rightarrow \text{AgCl} + \text{NH}_4^+$$
- g) Solid sodium oxide is added to distilled water.
$$\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{Na}^+ + \text{OH}^-$$
- h) A strip of zinc is added to a solution of 6.0-molar hydrobromic acid.
$$\text{Zn} + \text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2$$

1999 C

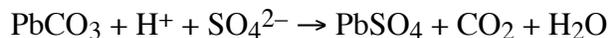
- a) Calcium oxide powder is added to distilled water.
$$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 \text{ (or } \text{Ca}^{2+} + \text{OH}^-)$$

Equations

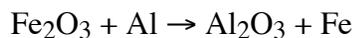
- c) Liquid bromine is shaken with 0.5*M* sodium iodide solution.



- d) solid lead(II) carbonate is added to a 0.5*M* sulfuric acid solution.



- e) A mixture of powdered iron(III) oxide and powdered aluminum metal is heat strongly.



- f) Methylamine gas is bubbled into distilled water.



- g) Carbon dioxide gas is passed over hot, solid sodium oxide.



- h) A 0.2*M* barium nitrate solution is added to an alkaline 0.2*M* potassium chromate solution.

