Reaction Guidelines

Students choose five of the eight reactions. Only the answers in the boxes are graded (unless clearly marked otherwise). Each correct answer earns 3 points, 1 point for reactants and 2 points for products. All products must be correct to earn both product points. Equations do not need to be balanced and phases need not be indicated. Any spectator ions on the reactant side nullify the 1 possible reactant point, but if they appear again on the product side, there is no product-point penalty. A fully molecular equation (when it should be ionic) earns a maximum of one point. Ion charges must be correct.

1999 AP Reaction Problem

(a) Calcium oxide powder is added to distilled water.

CaO +
$$H_2O \rightarrow Ca(OH)_2$$

No penalty for the set of products { Ca^{2+} , OH^- , and $Ca(OH)_2$ }

(b) Solid ammonium nitrate is heated to temperatures above 300°C.

$$NH_4NO_3 \rightarrow N_2 + O_2 + H_2O$$
 OR
 $NH_4NO_3 \rightarrow N_2O + H_2O$

Two points earned for $NH_4NO_2 \rightarrow N_2 + H_2O$

No penalty for other oxides of nitrogen (e.g., NO_2 , NO_3 , NO_4 - but not NO_5)

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

$$Br_2 + I^- \rightarrow Br^- + I_2$$

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

PbCO₃ + H⁺ + HSO₄⁻ (or SO₄²⁻)
$$\rightarrow$$
 PbSO₄ + CO₂ + H₂O (or HCO₃⁻)
No reactant point earned for H₂SO₄
No product point earned for H₂CO₃

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

Fe₂O₃ + Al
$$\rightarrow$$
 Al₂O₃ + Fe
No penalty for the set of products { FeO, Fe, and Al₂O₃ }

(f) Methylamine gas is bubbled into distilled water.

$$CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$$

Two points earned for MeNH₂ + H₂O \rightarrow MeNH₃⁺ + OH⁻

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

$$CO_2 + Na_2O \rightarrow Na_2CO_3$$

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

$$Ba^{2+} + CrO_4^{2-} \rightarrow BaCrO_4$$

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

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

Two points earned if only error is wrong symbol for tin (e.g., Ti)

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

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

(c) Ethene gas is burned air.

$$C_2H_4 + O_2 \rightarrow CO_2 + H_2O$$

No penalty for other oxidized forms of carbon as products (e.g.,C, CO)

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

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

One point earned for $H^+ + OH^- \rightarrow H_2O$
Two points earned for removal of H^+ from any $H_xP_yO_z$ species and H_2O as product

(e) Solid calcium sulfite is heated in a vacuum.

$$CaSO_3 \rightarrow CaO + SO_2$$

Two points earned for $CaSO_4$ $CaO + SO_3$

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

$$H^{+}$$
 + Cl⁻ + [Ag(NH₃)₂]⁺ → AgCl + NH₄⁺
Cl⁻ + [Ag(NH₃)₂]⁺ → AgCl + NH₃ (or NH₄⁺) earns two points
 H^{+} + [Ag(NH₃)₂]⁺ → Ag⁺ + NH₄⁺ earns two points

(g) Solid sodium oxide is added to distilled water.

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

Two points earned if reactants correct but only product is NaOH

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

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

Two points earned for $Zn + H^+ + Br^- \rightarrow ZnBr_2 + H_2$
Two points earned for $Zn + HBr \rightarrow Zn^{2+} + Br^- + H_2$

(a) Excess potassium hydroxide solution is added to a solution of aluminum nitrate.

$$Al^{3+} + OH^{-} \rightarrow Al(OH)_{3}$$

Other acceptable products: $Al(OH)_{4-}$; $Al(OH)_{4-}$; $Al(OH)_{4-}$; $Al_{2}O_{3-}$; $Al_{$

(b) A solution of sodium bromide is added to an acidified solution of potassium bromate.

$$H^+ + Br^- + BrO_3^- \rightarrow Br_2 + H_2O$$

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

$$SO_2 + H_2O \rightarrow H_2SO_3$$

other acceptable products: H⁺ + HSO₃⁻ or H⁺ + HSO₃⁻ + SO₃²⁻

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

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

$$H_2 + FeO \rightarrow H_2O + Fe$$

(f) Solid potassium amide is added to distilled water.

$$KNH_2 + H_2O \rightarrow NH_3 + OH^- + K^+$$

other acceptable products: $NH_4OH + OH^- + K^+$

(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 $Ni^{2+} + HS^- \rightarrow NiS + H^+$

(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.

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

hydrated ions acceptable with correct charge 1 point for Ni(OH)₂ as product

(c) Equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed.

$$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^{-}$$

incorrect charge on $H_2PO_4^-$ when only one product occurs, 1 point only 1 product point for transfer if H^+ from an ionic reactant to product when a phosphate species is incorrectly but consistently written.

(d) Chlorine gas is bubbled into a solution of sodium bromide.

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

no credit for monatomic CI as reactant or Br as product

(e) Ammonia gas is bubbled into a solution of ethanoic (acetic) acid.

NH₃ + HC₂H₃O₂
$$\rightarrow$$
 C₂H₃O₂⁻ + NH₄⁺
1 product point for NH₄C₂H₃O₂
1 point for NH₃ + H⁺ \rightarrow NH₄

(f) Solid ammonium carbonate is added to a saturated solution of barium hydroxide.

$$(NH_4)_2CO_3 + Ba^{2+} + OH^- \rightarrow NH_3 + BaCO_3 + H_2O$$

1 product point for either NH_3 or $BaCO_3$
2 product points for all three species correct

(g) Drops of liquid dinitrogen trioxide are added to distilled water.

$$N_2O_3 + H_2O \rightarrow HNO_2$$

1 product point for H⁺ + NO₂⁻

(h) Solutions of potassium permanganate and sodium oxalate are mixed.

$$MnO_4^- + C_2O_4^{2-} \rightarrow MnO_2 + CO_2$$

no penalty for OH⁻ or H₂O in equation
no point earned for Mn²⁺ as product

(a) Ethanol is burned in oxygen.

(b) Solid barium oxide is added to distilled water.

BaO +
$$H_2O \rightarrow Ba^{2+} + OH^-$$

Only 1 product point awarded for Ba(OH)₂

(c) Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.

$$Cl_2 + OH^- \rightarrow Cl^- + ClO^- (+ H_2O)$$

both an oxidized and a reduced form of CI necessary for 2 product points H_2O not necessary as product both CIO^- and CIO_2^- acceptable as oxidized forms of CI 1 point deducted if acidic products shown (e.g., H^+ , HCIO, HCI)

(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 $Fe(OH)_3$
 Fe^{3+} , $Fe^{3+} + OH^-$, and FeO_2 or Fe_3O_4 awarded only 1 product point

(e) Excess concentrated sulfuric acid is added to solid calcium phosphate.

$$H_2SO_4 + Ca_3(PO_4)_2 \rightarrow H_3PO_4 + CaSO_4$$

no ionized form of H_3PO_4 acceptable
 $CaSO_4$ may appear as $Ca^{2+} + SO_4^{2-}$, or $Ca^{2+} + HSO_4^{-}$, or $Ca(HSO_4)_2$

(f) Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.

$$H_2S + Hg^{2+} \rightarrow HgS + H^+$$

OR

 $H_2S + HgCl_2 \rightarrow HgS + H^+ + Cl^-$

If reactant is $HgCl_2$, products must include Cl^-

(g) Solid calcium hydride is added to distilled water.

$$CaH_2 + H_2O \rightarrow Ca^{2+} + OH^-$$
 (or $Ca(OH)_2$) + H_2
no ionized form of CaH_2 is acceptable; no H^- as a reactant

(h) A bar of zinc metal is immersed in a solution of copper(II) sulfate.

$$7n + Cu^{2+} \rightarrow 7n^{2+} + Cu$$

(a) Excess sodium cyanide is added to a solution of silver nitrate.

$$CN^- + Ag^+ \rightarrow Ag(CN)_2^-$$

Note: any complex ion of Ag⁺ with cyanide with consistent charge earns 3 points; AgCN given as product earns one product point.

(b) Solutions of manganese(II) sulfate and ammonium sulfide are mixed.

$$Mn^{2+} + S^{2-} \rightarrow MnS$$

Note: If Mg is used instead of Mn, maximum possible score is two points.

(c) Phosphorous(V) oxide powder is sprinkled over distilled water.

$$P_4O_{10}$$
 (or P_2O_5) + $H_2O \rightarrow H_3PO_4$

Note: Acidic species (H⁺ or oxyacid of phosphorous) earns one product point; P in +5 oxidation state in oxyanion earns one product point; anions of oxyacids of phosphorous require H⁺ for full credit for products.

(d) Solid ammonium carbonate is heated.

$$(NH_4)_2CO_3 \rightarrow NH_3 + H_2O + CO_2$$

Note: any one product earns one point; all three earn two points. $NH_4OH + CO_2$ earns one product point. $NH_3 + H_2CO_3$ earns one product point.

(e) Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide.

$$CO_2 + OH^- \rightarrow HCO_3^-$$

Note: $CO_3^{2-} + H_2O$ as products earns two product points. CO_3^{2-} alone as product earns one product point. $HCO_3^{-} + H_2O$ earns one product point.

(f) A concentrated solution of hydrochloric acid is added to solid potassium permanganate.

$$H^{+} + Cl^{-} + KMnO_{4} \rightarrow K^{+} + Mn^{2+} + Cl_{2} + H_{2}O$$

Note: HCl and MnO_4^- acceptable as reactants. Any valid redox product earns one point. All four product earns two points. K^+ and/or H_2O only as products earns no credit. If both H^+ and H_2O omitted, then maximum of two points possible.

(g) A small piece of sodium metal is added to distilled water.

$$Na + H_2O \rightarrow H_2 + Na^+ + OH^-$$

Note: all three products earn two product points. Any valid redox product earns one product point.

(h) A solution of potassium dichromate is added to an acidified solution of iron(II) chloride.

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

Note: All three products earn two product points. Any valid redox product earns one product point. H_2O only earns no credit. If $Cl^- \rightarrow Cl_2$ instead of $Fe^{2+} \rightarrow Fe^{3+}$, then maximum of two points possible.

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

Cu + H⁺ + NO₃⁻
$$\rightarrow$$
 Cu²⁺ + NO + H₂O
(1 pt for either Cu²⁺ or NO; NO₂ also accepted; 2 pts for all three.)

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

$$MnO_4^- + H_2O_2 \rightarrow Mn^{2+} + O_2 + H_2O$$

(1 pt for either Mn^{2+} or O_2 ; 2 pts for all three)

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

$$H^+ + MnS \rightarrow H_2S + Mn^{2+}$$

(d) Excess chlorine has is passed over hot iron filings.

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

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

 $(Mg^{2+} + OH^- \text{ also accepted})$

(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 + NH₃
$$\rightarrow$$
 Ag(NH₃)₂⁺ + Cl⁻ (other coordination numbers also accepted)

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

$$Zn^{2+} + PO_4^{3-} \rightarrow Zn_3(PO_4)_2$$

(a) An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.

$$Mg^{2+} + 2 OH^{-} \rightarrow Mg(OH)_{2}$$

(b) Solid lithium hydride is added to water.

LiH +
$$H_2O \rightarrow Li^+ + OH^- + H_2$$

OH⁻ or H_2 earns one point, all three for two points.

(c) Solutions of ammonia and hydrofluoric acid are mixed.

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

 $NH_3 + H^+ \rightarrow NH_4^+$ earns two points

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

$$AI + Ag^+ \rightarrow AI^{3+} + Ag$$

(e) A solution of potassium iodide is electrolyzed.

$$I^- + H_2O \rightarrow I_2 + H_2 + OH^-$$

 I_2 or H_2 (one point); all three products for two points

(f) Solid potassium oxide is added to water.

$$K_2O + H_2O \rightarrow K^+ + OH^-$$

KOH product alone is one point.

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

$$H^+ + Cu(NH_3)_4^{2+} \rightarrow Cu^{2+} + NH_4^{+}$$

(h) Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + HCO_3^{-}$$

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

$$Al_2O_3 + OH^- \rightarrow Al(OH)_4^-$$
OR
 $Al_2O_3 + H_2O \rightarrow Al(OH)_3$

(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.

$$H^{+} + OH^{-} \rightarrow H_{2}O$$

(d) Calcium metal is heated strongly in nitrogen gas.

$$Ca + N_2 \rightarrow Ca_3N_2$$

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

$$CuS + O_2 \rightarrow Cu + SO_2$$
 (also CuO, Cu₂O)

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

$$H^+ + Cl^- + MnO_2 \rightarrow Mn^{2+} + Cl_2 + H_2O$$
 (one pt. for either redox product, two pts. for all three products)

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

$$Zn^{2+} + NH_3 \rightarrow Zn(NH_3)_4^{2+}$$

OR
 $Zn^{2+} + NH_3 + H_2O \rightarrow Zn(OH)_2 + NH_4^+$

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

$$Cu^{2^+} + SO_4^{2^-} + Ba^{2^+} + OH^- \rightarrow Cu(OH)_2 + BaSO_4$$

A rare double precipitation.
Partial credit was allowed for some alternate solutions, e.g. $Cu^{2^+} + OH^- \rightarrow Cu(OH)_2$
 $Ba^{2^+} + SO_4^{2^-} \rightarrow BaSO_4$

(a) Solutions of sodium iodide and lead nitrate are mixed.

$$Pb^{2+} + 2l^{-} \rightarrow Pbl_{2}$$

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

Fe³⁺ + NH₃ + H₂O
$$\rightarrow$$
 Fe(OH)₃ + NH₄⁺ (NH₄OH is OK in place of NH₃ + H₂O)
Fe²⁺ + others above \rightarrow Fe(OH)₂ + NH₄⁺ (given two points)

(c) A solution of hydrogen peroxide is heated.

$$H_2O_2 \rightarrow H_2O + O_2$$

(d) Solutions of silver nitrate and sodium chromate are mixed.

$$Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4$$

(e) Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.

$$H_2S + OH^- \rightarrow S^{2-} (or HS^-) + H_2O$$

(f) Solid dinitrogen pentoxide is added to water.

$$N_2O_5 + H_2O \rightarrow H^+ + NO_3^-$$
 (HNO₃ = one point)

(g) A piece of solid bismuth is heated

$$Bi + O_2 \rightarrow Bi_2O_3$$
 (Bi_2O_5 = one point)

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

Cu + H⁺ + HSO₄⁻ (or SO₄²⁻)
$$\rightarrow$$
 Cu²⁺ + SO₂ + H₂O (any two products is given one point; all three must be there for 3 points; omitting H⁺ and/or H₂O is minus one point)

(a) Solutions of zinc sulfate and sodium phosphate are mixed.

$$Zn^{2+} + PO_4^{3-} \rightarrow Zn_3(PO_4)_2$$

(b) Solutions of silver nitrate and lithium bromide are mixed.

$$Ag^+ + Br^- \rightarrow AgBr$$

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

$$Cl_2 + OH^- \rightarrow OCI^- + CI^- + H_2O$$

(d) Excess hydrochloric acid solution is added to a solution of potassium sulfite.

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

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

$$Sn^{2+} + H^{+} + MnO_{4}^{-} \rightarrow Sn^{4+} + Mn^{2+} + H_{2}O$$

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

$$Fe^{3+} + SCN^{-} \rightarrow Fe(SCN)^{2+} (or Fe(SCN)_6^{3-})$$

(g) Samples of boron trichloride gas and ammonia gas are mixed.

$$BCI_3 + NH_3 \rightarrow CI_3BNH_3$$

(h) Carbon disulfide vapor is burned in excess oxygen.

$$CS_2 + O_2 \rightarrow CO_2 + SO_2$$
 (or SO_3)

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

$$H^+$$
 (or H_3O^+) + I^- + $Cr_2O_7^{2-} \rightarrow I_2$ + Cr^{3+} H_2O (Any reasonable I^- oxidation product accepted.)

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

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

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

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

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

$$KCIO_3 \rightarrow KCI + O_2$$

(MnO₂ is also shown over the reaction arrow in the original.)

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

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

(f) Sulfur trioxide gas is added to excess water.

$$SO_3 + H_2O \rightarrow H^+ + HSO_4^- \text{ (or } H^+ + SO_4^{2-}\text{)}$$

(g) Dilute sulfuric acid is added to a solution of barium chloride.

$$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$$

(or $Ba^{2+} + HSO_4^{-} \rightarrow BaSO_4 + H^+$)

(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 credit for other logical Cu(II) ammonia complexes and for Cu(OH)₂)

(a) Solid calcium is added to warm water.

Ca +
$$H_2O \rightarrow Ca(OH)_2 + H_2$$

Ca²⁺ + OH⁻ earns one point

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

$$MgO + CO_2 \rightarrow MgCO_3$$

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

$$H_2S + Ni^{2+} \rightarrow NiS + H^+$$

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

OH⁻ + Al(OH)₃
$$\rightarrow$$
 Al(OH)₄⁻
other acceptable answers:
Al(OH)₆³⁻
AlO₂⁻
Al(OH)₄(H₂O)₂⁻

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

$$Ag + H^{+} + NO_{3}^{-} \rightarrow Ag^{+} + NO (or NO_{2}) + H_{2}O$$

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

$$OH^{-} + H_{2}PO_{4}^{-} \rightarrow PO_{4}^{3-} + H_{2}O$$

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

$$H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + H_2O$$

 $Fe(OH)_3$ only as a product earns one point (Note: the scoring standard on this question has a two next to the formula, but in context of below, a one seems more appropriate)

(h) Propanol is burned completely in air.

$$C_3H_7OH + O_2 \rightarrow CO_2 + H_2O$$

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

$$Li + N_2 \rightarrow Li_3N$$

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

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

(c) Solid sodium oxide is added to water.

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

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

$$Zn^{2+} + S^{2-} \rightarrow ZnS$$

(or $Zn^{2+} + HS^{-} \rightarrow ZnS + H^{+}$)

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

$$NH_3 + HC_2H_3O_2 \rightarrow NH_4^+ + C_2H_3O_2^-$$

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

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

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

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$

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

$$Cl_2 + l^- \rightarrow l_2 + Cl^-$$

(a) Sodium metal is added to water.

$$Na + H_2O \rightarrow Na^+ + OH^- + H_2$$

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

$$H^{+} + HCO_{3}^{-} \rightarrow H_{2}O + CO_{2}$$
 (Part credit for $H_{2}CO_{3}$)

(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.

$$OH^{-} + Zn(OH)_{2} \rightarrow Zn(OH)_{4}^{2-}$$
 (or $Zn(OH)_{3}^{-}$ or $ZnO_{2}^{2-} + H_{2}O$)

(e) The gases boron trifluoride and ammonia are mixed.

$$BF_3 + NH_3 \rightarrow BF_3NH_3$$

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

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

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

$$POCI_3 + H_2O \rightarrow > H_3PO_4 + H^+ + CI^-$$

(h) An acidified solution of sodium permanganate is added to a solution of sodium sulfite.

$$MnO_4^- + SO_3^{2^-} + H^+ \rightarrow Mn^{2^+} + SO_4^{2^-} + H_2O$$

HSO₃ and HSO₄ were accepted.
(Part credit if H⁺ and H₂O were omitted)