

AP Review: Predicting Reactions (Question 4) **Answers**

For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

Grading: 1 pt for correct reactants, 2 pts correct products, 1 pt balancing mass and charge, 1 pt question.

2006 [These were in the old format—answer 5 out of 8—but have been rewritten in the current format]

- (a) Solid potassium chlorate is strongly heated and decomposes, resulting in a change in the oxidation numbers of both chlorine and oxygen.

(i) Balanced equation: $2 \text{KClO}_3 \rightarrow 2 \text{KCl} + 3 \text{O}_2$

(ii) What is the oxidation number of chlorine **before** and **after** the reaction? **Before = +5; after -1**

- (b) Solid silver chloride is added to a solution of concentrated hydrochloric acid, forming a complex ion.

(i) Balanced equation: $\text{AgCl} + \text{Cl}^- \rightarrow [\text{AgCl}_2]^-$

(ii) Which species acts as a Lewis base in the reaction? Explain. **Cl^- is a Lewis base because it donates an electron pair.**

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

(i) Balanced equation: $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$

(ii) Explain why a mixture of equal volumes of equimolar solutions of ethanoic acid and barium hydroxide is basic. **Since barium hydroxide has two moles of OH^- per mole, the mixture would have an excess of hydroxide, making it basic.**

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

(i) Balanced equation: $\text{NH}_3 + \text{HF} \rightarrow \text{NH}_4^+ + \text{F}^-$

(ii) Identify a conjugate acid-base pair in the reaction. **NH_3 (base) and NH_4^+ (acid) Or: HF (acid) and F^- (base).**

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

(i) Balanced equation: $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Cu} + \text{Zn}^{2+}$

(ii) Describe the change in color of the solution that occurs as the reaction proceeds. **$\text{Cu}^{2+}(\text{aq})$ is blue; $\text{Zn}^{2+}(\text{aq})$ is colorless so blue color fades.**

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

(i) Balanced equation: $\text{PH}_3 + \text{BCl}_3 \rightarrow \text{H}_3\text{PBCl}_3$ **Note: PH_3BCl_3 also acceptable as product**

(ii) Which species acts as a Lewis acid in the reaction? Explain. **BCl_3 is a Lewis acid because it accepts the non-bonded pair of electrons from the phosphorus atom in PH_3 .**

- (g) A solution of nickel(II) bromide is added to a solution of potassium hydroxide.
- Balanced equation: $\text{Ni}^{2+} + 2 \text{OH}^- \rightarrow \text{Ni(OH)}_2$
 - Identify the spectator ions in the reaction mixture. $\text{Br}^-(\text{aq})$ and $\text{K}^+(\text{aq})$ are spectator ions.
- (h) Hexane is combusted in air.
- Balanced equation: $2 \text{C}_6\text{H}_{14} + 19 \text{O}_2 \rightarrow 12 \text{CO}_2 + 14 \text{H}_2\text{O}$
 - When one molecule of hexane is completely combusted, how many molecules of products are formed?
13 molecules of product are formed.

2007

- (a) A solution of sodium hydroxide is added to a solution of lead(II) nitrate.
- Balanced equation: $2 \text{OH}^- + \text{Pb}^{2+} \rightarrow \text{Pb(OH)}_2$
 - If 1.0 L volumes of 1.0 M solutions of sodium hydroxide and lead(II) nitrate are mixed together, how many moles of product(s) will be produced? Assume the reaction goes to completion.
A total of 0.5 mol of Pb(OH)_2 will be produced
- (b) Excess nitric acid is added to solid calcium carbonate.
- Balanced equation: $2 \text{H}^+ + \text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{H}_2\text{O} + \text{CO}_2$
 - Briefly explain why statues made of marble (calcium carbonate) displayed outdoors in urban areas are deteriorating. The H^+ ions in acid rain react with the marble statues and the soluble compounds of Ca that are formed wash away.
- (c) A solution containing silver(I) ion (an oxidizing agent) is mixed with a solution containing iron(II) ion (a reducing agent).
- Balanced equation: $\text{Ag}^+ + \text{Fe}^{2+} \rightarrow \text{Ag} + \text{Fe}^{3+}$
 - If the contents of the reaction mixture described above are filtered, what substance(s), if any, would remain on the filter paper. The precipitated solid silver will remain on the filter paper

2007 Form B

- (a) Solid ammonium carbonate decomposes as it is heated.
- Balanced equation: $(\text{NH}_4)_2\text{CO}_3 \rightarrow 2 \text{NH}_3 + \text{H}_2\text{O} + \text{CO}_2$
 - Predict the algebraic sign of ΔS° for the reaction. Explain your reasoning.
 ΔS° will be positive, an increase in entropy as one mole of solid (with relatively low entropy) is converted into four moles of gas (with much greater entropy).
- (b) Chlorine gas, an oxidizing agent, is bubbled into a solution of potassium bromide.
- Balanced equation: $\text{Cl}_2 + 2 \text{Br}^- \rightarrow 2 \text{Cl}^- + \text{Br}_2$
 - What is the oxidation number of chlorine before the reaction occurs? What is the oxidation number of chlorine after the reaction occurs? before 0, after -1

- (c) A small piece of sodium is placed in a beaker of distilled water.
- Balanced equation: $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^- + \text{H}_2$
 - The reaction is exothermic, and sometimes small flames are observed as the sodium reacts with the water. Identify the product of the reaction that burns to produce the flames.
It is the H_2 gas that burns

2008

- (a) Aqueous sodium hydroxide is added to a saturated solution of aluminum hydroxide, forming a complex ion.
- Balanced equation: $\text{Al}(\text{OH})_3 + \text{OH}^- \rightarrow [\text{Al}(\text{OH})_4]^-$ OR $\text{Al}(\text{OH})_3 + 3\text{OH}^- \rightarrow [\text{Al}(\text{OH})_6]^{3-}$ OR $\text{Al}^{3+} + 4\text{OH}^- \rightarrow [\text{Al}(\text{OH})_4]^-$ OR $\text{Al}^{3+} + 6\text{OH}^- \rightarrow [\text{Al}(\text{OH})_6]^{3-}$
 - If the resulting mixture is acidified, would the concentration of the complex ion increase, decrease, or remain the same? Explain.
The H^+ added would react with the OH^- in solution, reducing the $[\text{OH}^-]$ and shifting the equilibrium toward the reactants, thus reducing the concentration of the complex ion. OR (If the reaction has gone to completion), the H^+ added would react with the $[\text{Al}(\text{OH})_4]^-$, thus reducing the concentration:
 $[\text{Al}(\text{OH})_4]^- + \text{H}^+ \rightarrow \text{Al}(\text{OH})_3 + \text{H}_2\text{O}$
- (b) Hydrogen chloride gas is oxidized by oxygen gas.
- Balanced equation: $4\text{HCl} + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + 2\text{Cl}_2$ OR $4\text{HCl} + 3\text{O}_2 \rightarrow 2\text{H}_2\text{O} + 4\text{ClO}$ OR products ClO_2 , or ClO_3 or HClO or HClO_2 or HClO_3 or HClO_4
 - If three moles of hydrogen chloride gas and three moles of oxygen gas react as completely as possible, which reactant, if any, is present in excess? Justify your answer.
Must be consistent with equation in (i)
- (c) Solid potassium oxide is added to water.
- Balanced equation: $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{K}^+ + 2\text{OH}^-$
 - If a few drops of phenolphthalein are added to the resulting solution, what would be observed? Explain.
The solution would turn pink because OH^- makes the solution basic; phenolphthalein turns pink in base.

2008 Form B

- (a) Chlorine gas, an oxidizing agent, is bubbled into a solution of potassium bromide at 25°C .
- Balanced equation: $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$
 - Predict the algebraic sign of ΔS° for the reaction. Explain your reasoning. The sign of ΔS° is negative. One of the reactants, Cl_2 , is a gas at 25°C , but there are no gaseous products. Gases have high entropy, so the entropy of the reactants is greater than the entropy of the products, making $\Delta S^\circ < 0$.
- (b) Solid strontium hydroxide is added to a solution of nitric acid.
- Balanced equation: $\text{Sr}(\text{OH})_2 + 2\text{H}^+ \rightarrow \text{Sr}^{2+} + 2\text{H}_2\text{O}$
 - How many moles of strontium hydroxide would react completely with 500. mL of 0.40 M nitric acid?
 $500\text{ mL} \times 0.40\text{ M HNO}_3 = 0.20\text{ mol H}^+ \times 1\text{ mol Sr}(\text{OH})_2 / 2\text{ mol OH}^- = 0.10\text{ mol Sr}(\text{OH})_2$ needed.

- (c) A solution of barium chloride is added drop by drop to a solution of sodium carbonate, causing a precipitate to form.
- (i) Balanced equation: $\text{Ba}^{2+} + \text{CO}_3^{2-} \rightarrow \text{BaCO}_3$
- (ii) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?
 A solution of sodium carbonate is basic. When carbonate precipitates out, this decreases the pH.

2009

- (a) A sample of solid iron(III) oxide is reduced completely with solid carbon.
- (i) Balanced equation: $2 \text{Fe}_2\text{O}_3 + 3 \text{C} \rightarrow 4 \text{Fe} + 3 \text{CO}_2$ OR $\text{Fe}_2\text{O}_3 + 3 \text{C} \rightarrow 2 \text{Fe} + 3 \text{CO}$
- (ii) What is the oxidation number of carbon before the reaction, and what is the oxidation number of carbon after the reaction is complete?
 Before = 0; after = +4
- (b) Equal volumes of equimolar solutions of ammonia and hydrochloric acid are combined.
- (i) Balanced equation: $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ OR $\text{NH}_3 + \text{H}_3\text{O}^+ \rightarrow \text{NH}_4^+ + \text{H}_2\text{O}$
- (ii) Indicate whether the resulting solution is acidic, basic, or neutral. Explain.
 The resulting solution is acidic because of the hydrolysis of the NH_4^+ ion, which reacts with water to form NH_3 and H^+ OR the mixing of a strong acid and a weak base results in an acidic solution.
- (c) Solid mercury(II) oxide decomposes as it is heated in an open test tube in a fume hood.
- (i) Balanced equation: $2 \text{HgO} \rightarrow 2 \text{Hg} + \text{O}_2$
- (ii) After the reaction is complete, is the mass of the material in the test tube greater than, less than, or equal to the mass of the original sample? Explain. The mass of the contents of the test tube will decrease owing to the loss of O_2 gas to the atmosphere.

2009 Form B

- (a) A barium nitrate solution and a potassium fluoride solution are combined and a precipitate forms.
- (i) Balanced equation: $\text{Ba}^{2+} + 2 \text{F}^- \rightarrow \text{BaF}_2$
- (ii) If equimolar amounts of barium nitrate and potassium fluoride are combined, which reactant, if any, is the limiting reactant? Explain. According to the balanced equation, twice as much KF is required to completely react with the barium nitrate. Because there are equimolar amounts of barium nitrate and potassium fluoride, there is not enough potassium fluoride to react with all of the barium nitrate, so potassium fluoride is the limiting reactant.
- (b) A piece of cadmium metal is oxidized by adding it to a solution of copper(II) chloride.
- (i) Balanced equation: $\text{Cd} + \text{Cu}^{2+} \rightarrow \text{Cd}^{2+} + \text{Cu}$
- (ii) List two visible changes that would occur in the reaction container as the reaction is proceeding.
 In the solution, the blue color of the copper(II) cation would decrease and eventually the solution would become colorless. Reddish brown (or black) copper metal would plate out onto the piece of silvery cadmium metal.
- (c) A hydrolysis reaction occurs when solid sodium sulfide is added to distilled water.
- (i) Balanced equation: $\text{Na}_2\text{S} + \text{H}_2\text{O} \rightarrow 2 \text{Na}^+ + \text{HS}^- + \text{OH}^-$ OR $\text{Na}_2\text{S} + 2\text{H}_2\text{O} \rightarrow 2\text{Na}^+ + \text{H}_2\text{S} + 2\text{OH}^-$
- (ii) Indicate whether the pH of the resulting solution is less than 7, equal to 7, or greater than 7. Explain.
 The pH of the resulting solution is greater than 7. The hydrolysis reaction of S^{2-} produces the base OH^- , thus raising the pH above 7.

2010

(a) A 0.2 M potassium hydroxide solution is titrated with a 0.1 M nitric acid solution



(ii) What would be observed if the solution was titrated well past the equivalence point using bromthymol blue as the indicator? (Bromothymol blue is yellow in acidic solution and blue in basic solution.)

The solution would appear yellow.

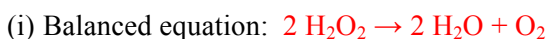
(b) Propane is burned completely in excess oxygen gas.



(ii) When the products of the reaction are bubbled through distilled water, is the resulting solution neutral, acidic, or basic? Explain.

The resulting solution would be acidic because CO_2 reacts with water as a weak acid.

(c) A solution of hydrogen peroxide is heated, and a gas is produced.



(ii) Identify the oxidation state of oxygen in hydrogen peroxide. The oxidation state of O in H_2O_2 is -1

2010 Form B

(a) Solid copper(II) sulfate pentahydrate is gently heated.



(ii) How many grams of water are present in 1.00 mol of copper(II) sulfate pentahydrate?

$$1.00 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O} \times 5 \text{ mol H}_2\text{O} / 1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O} \times 18.0 \text{ g H}_2\text{O} / \text{mol H}_2\text{O} = 90.0 \text{ g H}_2\text{O}$$

(b) Excess concentrated aqueous ammonia is added to a solution of nickel(II) nitrate, leading to the formation of a complex ion.



(ii) Which of the reactants acts as a Lewis acid? Ni^{2+}

(c) Methylamine (CH_3NH_2) is added to a solution of hydrochloric acid.



(ii) Methylamine dissolves in water to form a solution. Indicate whether this solution is acidic basic, or neutral. The solution would be basic (because it would react with water to form CH_3NH_3^+ ions and OH^- ions).

2011

(a) Solid magnesium hydroxide is added to a solution of hydrobromic acid.



(ii) What volume, in mL, of 2.00 M hydrobromic acid is required to react completely with 0.10 mol of solid magnesium hydroxide?

$$\text{mol H}^+ = 0.10 \text{ mol Mg}(\text{OH})_2 \times 2 \text{ mol H}^+/\text{mol Mg}(\text{OH})_2 = 0.20 \text{ mol H}^+$$

$$0.20 \text{ mol H}^+ \times 1.00 \text{ L}/2.00 \text{ mol H}^+ \times 1000 \text{ mL}/1.00 \text{ L} = 100 \text{ mL}$$

(b) Excess hydrochloric acid is added to a solution of cobalt(II) nitrate to produce a coordination complex.



(ii) Which species in the reaction acts as a Lewis base? Cl^- functions as a Lewis base

(c) A copper wire is dipped into a solution of silver(I) nitrate.



(ii) Describe what is observed as the reaction proceeds.

Silver metal will appear on the surface of the copper wire. OR The solution will turn blue. OR the copper wire will lose mass.

2011 Form B

(a) Zinc metal is added to a hydrobromic acid solution.



(ii) Write the oxidation half-reaction for the reaction. $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$

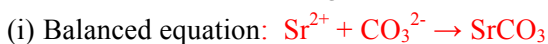
(b) Solid lithium oxide is added to distilled water



(ii) Indicate whether the pH of the resulting solution is less than 7, equal to 7, or greater than 7. Explain.

The pH of the resulting solution would be greater than 7 b/c OH^- , a strong base, is formed in the reaction.

(c) A 100-mL sample of 1 M strontium chloride solution is mixed with a 100 mL sample of 1 M sodium carbonate solution, resulting in the formation of a precipitate.



(ii) Describe what will occur if the precipitate is dried and a few drops of 1 M hydrochloric acid are added. Explain.

The precipitate disappears and bubbles of CO_2 form