Section 7.3: Which Reagent Runs Out First?

Mini Investigation: Balloon Stoichiometry, page 327
Answers may vary. Sample answers:
A. The balloon on Bottle 1 was the smallest in size. The balloon on Bottle 4 was the next smallest in size. The balloons on Bottle 7 and Bottle 10 were identical in size and the largest.
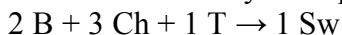**B.** The balloons on Bottle 7 and Bottle 10 were equally large because the sodium hydrogen carbonate in these bottles was completely used up by the other reactant, ethanoic acid, in the reaction.
C. In Bottle 1 and Bottle 4, ethanoic acid is the limiting reagent and sodium hydrogen carbonate is the excess reagent. We know this because increasing the quantity of ethanoic acid used produced more carbon dioxide gas. Adding more ethanoic acid to these bottles after the reaction has stopped should produce more gas since some sodium hydrogen carbonate remains.

In Bottle 7 and Bottle 10, sodium hydrogen carbonate is the limiting reagent and ethanoic acid is the excess reagent since increasing the quantity of ethanoic acid from Bottle 7 to Bottle 10 had no effect on the size of the balloon in Bottle 7. Adding sodium hydrogen carbonate to these bottles should produce more gas, proving that some unreacted ethanoic acid remains.

Section 7.3 Questions, page 330
1. Answers may vary. Sample answer: The number of sandwiches that can be made depends on the quantity of ingredients present. For example, a particular sandwich (Sw) consists of 2 slices of bread (B), 3 slices of cheese (Ch), and 1 slice of tomato (T). The process of making the sandwiches is described by the equation
$$2\,B + 3\,Ch + 1\,T \rightarrow 1\,Sw$$
From 5 slices of bread, 7 slices of cheese, and 2 slices of tomato, only 2 sandwiches can be made. In this case, the quantity of tomato slices limits the quantity of sandwiches made. Therefore, tomato slices are analogous to the limiting reagent. The items that remain are 1 bread slice and 1 cheese slice. They are analogous to the excess reagents.
2. (a) Since the ratio of nitrogen to hydrogen in the balanced equation is 1:3, only 3 nitrogen molecules are required to react with 9 molecules of hydrogen. As a result, 1 molecule of nitrogen remains. Therefore, the limiting reagent is hydrogen and the excess reagent is nitrogen.
(b) From the balanced equation, 3 molecules of hydrogen produce 2 molecules of ammonia. The maximum number of ammonia molecules that can be made from 9 hydrogen molecules is 6.
(c) One molecule of nitrogen is in excess.
3. (a) $Mg(s) + 2\,HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$
(b) The reaction is a single displacement reaction.
(c) In Trials 1 and 2, magnesium is the limiting reagent and hydrochloric acid is the excess reagent. We know this because increasing the quantity of magnesium produced more hydrogen gas. In Trials 3 and 4, hydrochloric acid is the limiting reagent and magnesium is the excess reagent since increasing the quantity of magnesium from Trial 3 to Trial 4 had no effect on the size of the balloon in Trial 3.
4. (a) Covering a pot containing a grease fire with a lid limits the quantity of oxygen available for the combustion of grease. The lack of oxygen stops the reaction and extinguishes the flame. In this case, oxygen gas is the limiting reagent and grease is the excess reagent.

(b) Since the addition of sodium sulfide solution precipitates all the iron ions in the contaminated gunpowder, no more iron ions remain. In this case, the sodium sulfide solution is the excess reagent and the iron ions are the limiting reagent.

5. In order to recover as much silver as possible, silver chloride must be the limiting reagent while the other two reactants, sodium hydroxide solution and zinc metal, are excess reagents. This ensures that all the silver chloride present reacts.

6. To remove as much sulfur dioxide as possible, an excess of both calcium carbonate and oxygen gas must be used. Therefore, calcium carbonate and oxygen gas should be the excess reagents.

7. (a) Since the ratio of gold(III) sulfide to hydrogen gas in the balanced equation is 1:3, 15 mol of hydrogen is required to react completely with 5 mol of gold(III) sulfide. Only 13 mol of hydrogen is present. This amount is less than what is required. Therefore, hydrogen is the limiting reagent and gold(III) sulfide is the excess reagent.

(b) The process is most profitable when the maximum quantity of gold is extracted. This is achieved when gold(III) sulfide is the limiting reagent while the other reactants are excess reagents.

8. Answers may vary. Sample answer: The role of the oxygen sensor in an automobile engine is to help the vehicle operate as efficiently as possible while keeping harmful emissions to a minimum. The oxygen sensor is often located in the exhaust pipe where it monitors the combustion gases. If the mixture is too rich in fuel, incomplete combustion occurs, resulting in more unburned hydrocarbons emitted in the exhaust. A mixture that is too lean in fuel results in an increased production of nitrogen oxides. After completing its analysis of the exhaust gases, the oxygen sensor sends an electrical signal to the engine's computer which adjusts the amount of fuel accordingly.

9. Answers may vary. Sample answer: EDTA is a chemical that binds dissolved metals in body fluids and prevents the metals from interfering with naturally occurring processes in the body. The EDTA-metal complex ions are then eliminated from the body in urine.

10. Answers may vary. Sample answer: The burning of fuels emits carbon dioxide into the atmosphere. These carbon dioxide emissions are having a potentially harmful effect on our environment, leading to climate change and global warming. At the commercial level, the price of a gasoline engine car is cheaper than a diesel engine car of the same power, but the price of gasoline is higher than diesel. However, using gasoline as the fuel for cars seems to be better for the environment. Comparing the greenhouse gas emissions of diesel-powered and gasoline-powered cars is tricky. Diesel fuel contains 11 % more energy per volume of fuel burned but also releases 15 % more carbon dioxide. Diesel and gasoline vehicles differ in their emissions of other atmospheric pollutants. Diesel engines, in comparison with gasoline engines, emit less carbon monoxide, CO, but over 20 times more nitrogen oxides. These pollutants are harmful to the environment.