Making Connections

6. (a) The typical percentage yield of the carmine extraction process is 23% of 62% pure carmine. Carmine is extracted by boiling the insects in water, followed by filtration, precipitation, and washing and drying the final product.
   (b) Cochineal processing plants have boosted local employment in Peru. While they earn only about 10% of the revenue generated from cochineal processing, an estimated 50 000 people harvest the insects by hand, dry them in the sun, and sell them to carmine processors in Lima, Peru's capital city. It is estimated that as many as 400 000 rural families depend on this industry for their livelihood.

2.13 INVESTIGATION: PERCENTAGE YIELD OF A CHEMICAL REACTION

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Prediction

(a) mass of copper(II) chloride dihydrate used = 2.00 g

$$m_{Cu} = 2.00\ \cancel{\text{g } CuCl_2{\bullet}2H_2O} \times \frac{1\ \cancel{\text{mol } CuCl_2{\bullet}2H_2O}}{170.49\ \cancel{\text{g } CuCl_2{\bullet}2H_2O}} \times \frac{3\ \cancel{\text{mol Cu}}}{3\ \cancel{\text{mol } CuCl_2{\bullet}2H_2O}} \times \frac{63.55\ \text{g Cu}}{1\ \cancel{\text{mol Cu}}}$$

$$m_{Cu} = 0.745\ \text{g Cu}$$

The theoretical yield of copper is 0.745 g.
It is predicted that the actual yield will be approximately 10% lower than the theoretical yield, or 0.671 g.

Qualitative Observations

A reddish residue of copper formed immediately when the foil was added to the solution.
Vigorous bubbling was observed on the aluminum surface as the reaction started.
Some of the copper changed to a green colour after it was dried overnight.
The aluminum foil broke up into many small pieces as the reaction occurred.

Quantitative Observations

mass of copper(II) chloride dihydrate = 2.00 g
mass of 150-mL beaker and copper residue = 86.38 g
mass of empty 150-mL beaker = 85.97 g
mass of copper residue collected = 86.38 g – 85.97 g
mass of copper residue collected = 0.410 g

Analysis

(b) There were many small pieces of aluminum left in the beaker when the reaction had come to a halt. Therefore, aluminum is the excess reagent and copper(II) chloride dihydrate is the limiting reagent.
(c) 0.410 g of copper was formed when 2.00 g of copper(II) chloride dihydrate reacted with excess aluminum.
(d)

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{0.410\ \cancel{\text{g}}}{0.745\ \cancel{\text{g}}} \times 100\%$$

$$\text{percentage yield} = 55.0\%$$

The percentage yield of copper is 55.0%.

Evaluation

(e) The percentage yield was less than 100%. One possible source of experimental error is impurities in the copper(II) chloride dihydrate salt, which means there was less copper in the reactant that could be collected as a product. Also, the aluminum metal broke into many small pieces as the reaction occurred. Some copper could have stuck to the aluminum, and when the aluminum was removed it resulted in some of the copper also being removed.

A percentage yield greater than 100% may occur if some unreacted aluminum metal inadvertently remains mixed with the copper residue. The mass of copper will appear to be higher than it actually is, and the percentage yield of copper may be calculated to be higher than 100%.

(f) The reaction was allowed to continue until all visible bubbling ceased. That signalled the end of the reaction.

(g) You would have to reduce the amount of aluminum used and/or increase the amount of copper(II) chloride dihydrate used. Aluminum would be the limiting reagent if the aluminum disappeared before the solution lost its characteristic blue colour.

2.14 CASE STUDY: THE HABER PROCESS

CASE STUDY 2.14 QUESTIONS

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Understanding Concepts

1. Four factors that could affect the production of ammonia in the Haber process include the type of container (open or closed), effect of a catalyst, temperature, and pressure.
2. The reaction is too slow to be economical at low temperatures.
3. Iron oxide is used as a catalyst in the Haber process. Iron oxide speeds up the reaction, even at moderate temperatures.
4.