VANCOUVER COMMUNITY COLLEGE

Stoichiometry Problems

In a chemical reaction, we often know the quantity (in g, or mL of solution) of one compound involved in the reaction, but not the quantity of the other compounds. We can use the process of **stoichiometry** to figure out problems like this using these steps:

[1] Convert the mass or volume of the given species to moles by using the molar mass of the species.
[2] Convert the moles of the given species to moles of the desired species by using the ratio of coefficients in the chemical equation.
[3] Convert the moles of the desired species back into mass or volume by using the molar mass of the desired species.
[4] If needed, calculate percentage yield by comparing the theoretical yield (calculated in step [3]) to the actual yield as presented in the question, or as measured in an experiment:

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

Example 1: Consider the synthesis of ammonium sulphate:

$$2\ NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

Assuming an excess of sulphuric acid, determine the mass of ammonium sulphate produced (i.e., the theoretical yield) when 2.50 g of ammonium is reacted.

Solution: [1] Convert 2.50 g of ammonium to moles:

$$2.50\ \text{g}\ NH_3 \times \frac{1\ \text{mol}\ NH_3}{17.03\ \text{g}\ NH_3} = 0.147\ \text{mol}\ NH_3$$

[2] Convert moles of ammonium to moles of ammonium sulphate.

$$0.147\ \text{mol}\ NH_3 \times \frac{1\ \text{mol}\ (NH_4)_2SO_4}{2\ \text{mol}\ NH_3} = 0.0734\ \text{mol}\ (NH_4)_2SO_4$$

[3] Convert moles of ammonium

$$0.0734\ \text{mol}\ (NH_4)_2SO_4 \times \frac{132.14\ \text{g}\ (NH_4)_2SO_4}{1\ \text{mol}\ (NH_4)_2SO_4} = 9.70\ \text{g}\ (NH_4)_2SO_4$$

Example 2: If, in the experiment carried out in Example 1, only 7.25 grams of $(NH_4)_2SO_4$ was produced, what was the percentage yield?

Solution: $$\%\ \text{yield} = \frac{7.25\ \text{g}\ (NH_4)_2SO_4}{9.70\ \text{g}\ (NH_4)_2SO_4} \times 100\% = 74.7\%$$

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EXERCISES

A. The combustion of ethanol is given by the following equation:

$$\underset{\text{ethanol}}{C_2H_5OH} + \underset{\text{oxygen}}{3\,O_2} \rightarrow \underset{\text{carbon dioxide}}{2\,CO_2} + \underset{\text{water}}{3\,H_2O}$$

1) How many moles of oxygen are required to burn 2.62 moles of ethanol?

2) How many moles of carbon dioxide will be produced in the burning of 3.77 moles of ethanol?

3) How many moles of water will be produced along with 0.665 mol of carbon dioxide?

4) How many grams of ethanol can be burned by 2.37 mol of oxygen?

5) How many moles of water will result from the burning of 25.7 g of ethanol?

6) 6.22 g of oxygen are used in burning ethanol. How many moles of water will result?

7) How many grams of carbon dioxide will be produced by the combustion of 82.8 g of ethanol?

8) How many grams of oxygen must be used to produce 89.3 g of carbon dioxide?

B. In the Chemistry 071 *Organic Chemistry* experiment, aspirin is produced by the reaction of salicylic acid with acetic anhydride according to the following equation:

$$\underset{\text{salicylic acid}}{C_7H_6O_3} + \underset{\text{acetic anhydride}}{C_4H_6O_3} \rightarrow \underset{\text{aspirin}}{C_9H_8O_4} + \underset{\text{acetic acid}}{C_2H_4O_2}$$

1) How many grams of aspirin can be prepared from 5.25 g of salicylic acid? (This is the *theoretical yield*.)

2) In the experiment, water is used to wash the aspirin produced. As a result, some of the aspirin will be lost due to its solubility in water (0.25 $^{g}/_{100\ \text{mL water}}$). If 90.0 mL of water was used to wash the aspirin produced, how much aspirin will be lost?

3) Using your results from (2), determine the theoretical yield of aspirin corrected for its solubility in water.

4) If it was found experimentally that the yield of aspirin was 5.87 g, what is the percentage yield of aspirin?

C. Consider the following reaction:

$$\underset{\text{phosgene}}{COCl_2} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{carbon dioxide}}{CO_2} + \underset{\text{hydrochloric acid}}{2\,HCl(aq)}$$

1) How many moles of hydrochloric acid are produced by the reaction of 1.43 mol of phosgene?

D. Consider the following reaction:

$$\underset{\text{ammonium chloride}}{2\,NH_4Cl} + \underset{\text{calcium oxide}}{CaO} \rightarrow \underset{\text{ammonia}}{2\,NH_3} + \underset{\text{calcium chloride}}{CaCl_2} + \underset{\text{water}}{H_2O}$$

1) 6.28 g of ammonia are produced by this reaction. How many grams of calcium chloride are also produced?

SOLUTIONS

A. (1) 7.86 mol (2) 7.54 mol (3) 0.998 mol (4) 36.4 g (5) 1.67 mol (6) 0.194 mol (7) 158 g (8) 97.4 g

B. (1) 6.85 g (2) 0.225 g lost (3) 6.63 g (4) 88.6%

C. (1) 2.86 mol D. (1) 20.5 g