

# Applications of Stoichiometry

1. How many grams of calcium chloride can be prepared from 60.4 g of calcium oxide and 69.0 g of hydrochloric acid in a double displacement reaction?

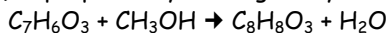
2. How many grams of aluminum sulfate form when 6.71 g of aluminum reacts with 12.95 g of sulfuric acid?

3. Aspirin,  $C_9H_8O_4$ , is prepared by heating salicylic acid,  $C_7H_6O_3$ , with acetic anhydride,  $C_4H_6O_3$ :



If 4.00 g of salicylic acid are heated with 8.00 g of acetic anhydride, what is the theoretical yield? If the actual yield of aspirin is 4.36 g, what is the percent yield?

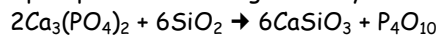
4. Oil of wintergreen (methyl salicylate) is prepared by heating salicylic acid,  $C_7H_6O_3$ , with methanol,  $CH_3OH$ :



If 4.50 g of salicylic acid is reacted with excess methanol and the yield of oil of wintergreen is 3.73 g, what is the percent yield?

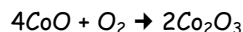
5. In an experiment 10.80 g of butanoic acid,  $C_4H_8O_2$ , was heated with 3.40 g of ethanol,  $C_2H_5OH$ , to produce ethyl butanoate,  $C_6H_{12}O_2$ , and water. What is the theoretical yield of the ethyl butanoate? If the actual yield was 5.57 g, what is the percent yield?

6. Phosphorus oxide is extracted from phosphate-containing rocks by reaction with silicon dioxide found in sand:



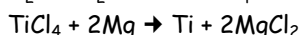
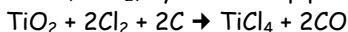
If 1.00 t of sand that is 60.0 silicon dioxide is used, how many kilograms of tetraphosphorus decoxide could be produced?

7. A tank of impure carbon monoxide contains 6.8 g of oxygen impurity per 100.0 kg of gas. The oxygen is removed by reacting it with cobalt(II) oxide:



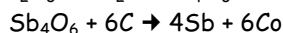
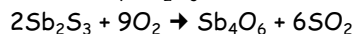
How many grams of impure gas can be purified by passing it through a column containing 47.9 g of cobalt(II) oxide?

8. Titanium is produced from the mineral rutile,  $TiO_2$ , by a two-step process:



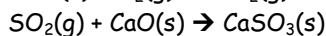
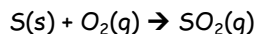
How many kilograms of titanium can be obtained from 1.00 t of rutile?

9. Antimony is usually found as the mineral stibnite,  $Sb_2S_3$ . Pure antimony can be obtained by a two-step process:



How many grams of antimony can be obtained from 1.00 kg of stibnite?

10. Coal from a certain mine contains 2.80% sulfur. When the coal is burned at a power generating station, the sulfur is converted to calcium sulfite. If 1200.0 t of coal is burned at the power plant each day, what is the daily output of calcium sulfite?



11. The mass percentage of chloride ion in a 25.00 mL sample of seawater was determined by titrating the sample with silver nitrate, causing the precipitation of silver chloride. It required 42.58 mL of 0.2997 M silver nitrate solution to reach the equivalence point in the titration. What is the mass percentage of chloride ion in the seawater if its density is 1.025 g/mL?

12. Aspirin ( $C_9H_8O_4$ ) is produced commercially from salicylic acid ( $C_7H_6O_3$ ) and acetic anhydride ( $C_4H_6O_3$ ) according to the equation:



- a) If all of the salicylic acid is converted to aspirin, how much salicylic acid is required to prepare 175 kg of aspirin?
- b) If only 75.0% of the salicylic acid is converted to aspirin, how much salicylic acid would be required to prepare 175 kg of aspirin?
- c) If salicylic acid costs \$10.00/kg and acetic anhydride costs \$13.00/kg, which compound would you choose as the limiting reactant in order to have the most economical process? Justify your answer.
- d) What is the theoretical yield of aspirin if 205 kg of salicylic acid are allowed to react with 140.0 kg of acetic anhydride?
- e) If the actual yield of aspirin from part (d) is 202 kg, what is the percent yield?
- f) What would you have to charge for a kilogram of aspirin to cover the cost of the raw materials? (Ignore the cost of labour, electricity, machinery, taxes, etc.)
13. The Solvay process is an important commercial method of preparing sodium carbonate. In the first step of this process, ammonia, water and carbon dioxide react to produce ammonium bicarbonate. This product is then treated in the second step with sodium chloride to allow conversion to sodium bicarbonate. Finally, the sodium bicarbonate is heated, and sodium carbonate, carbon dioxide, and water are produced. If this process is initiated with a stream of ammonia flowing at the rate of 40.0 L/s, at what rate must carbon dioxide be supplied in the first step? How much sodium chloride (in grams per second) is required to permit the second step to occur as required? Finally, how much sodium carbonate (in grams), and how much carbon dioxide (in litres), are formed every second under these conditions?
14. HCN is a poisonous gas. The lethal dose is approximately 300.0 mg HCN per kilogram of air when inhaled.
- a) Calculate the amount of HCN that gives the lethal dose in a small laboratory room measuring 12 by 15 by 8.0 ft. The density of air at 26°C is 0.00118 g/cm<sup>3</sup>.
- b) If the HCN is formed by the reaction of NaCN with an acid such as H<sub>2</sub>SO<sub>4</sub>, what mass of NaCN gives the lethal dose in the room?
- $$2NaCN(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HCN(g)$$
- c) HCN forms when synthetic fibres containing Orlon® or Acrilan® burn. Acrilan has an empirical formula of CH<sub>2</sub>CHCN, and so HCN is 50.9% of the formula by mass. A rug measures 12 by 15 ft and contains 30 oz of Acrilan® fibres per square yard of carpet. If the rug burns, will a lethal dose of HCN be generated in the room? Assume that the yield of HCN from the fibres is 20% and the the carpet is 50% consumed.
- Conversions: 1 cm = 0.39370 in, 1 ft = 12 in, 1 kg = 2.2046 lb, 1 lb = 16 oz
15. Vinyl chloride is the raw material for the production of commercial plastic called PVC. Vinyl chloride contains only carbon, hydrogen, and chlorine, and it burns in air (oxygen) to form carbon dioxide, water vapour, and hydrogen chloride. If the combustion of 2.152 g of vinyl chloride produces 3.029 g of carbon dioxide and 1.257 g of hydrogen chloride, what is the empirical formula of vinyl chloride?
16. Menthol, the substance we can smell in mentholated cough drops, is composed of carbon, hydrogen, and oxygen. A 0.1005 g sample of menthol is combusted, producing 0.2829 g of carbon dioxide and 0.1159 g of water. What is the empirical formula for menthol?
17. The characteristic odour of pineapple is due to ethyl butyrate, a compound containing carbon, hydrogen, and oxygen. Combustion of 2.78 mg of ethyl butyrate produces 6.32 mg of carbon dioxide and 2.58 mg of water. What is the empirical formula of the compound?
18. Nicotine, a component of tobacco, is composed of carbon, hydrogen, and nitrogen. A 5.250 mg sample of nicotine was combusted, producing 14.242 mg of carbon dioxide and 4.083 mg of water. What is the empirical formula for nicotine?