

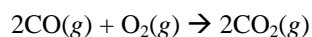
CHAPTER FOUR

Conversion Problem & Stoichiometry

4.37 On what law is stoichiometry based? Why is it essential to use balanced equations in solving stoichiometric problems?

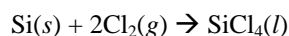
4.38 Describe the steps involved in the mole method.

4.39 Consider the combustion of carbon monoxide (CO) in oxygen gas:



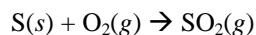
Starting with 3.60 moles of CO, calculate the number of moles of CO₂ produced if there is enough oxygen gas to react with all of the CO.

4.40 Silicon tetrachloride (SiCl₄) can be prepared by heating Si in chlorine gas:



In one reaction, 0.507 mole of SiCl₄ is produced. How many moles of molecular chlorine were used in the reaction?

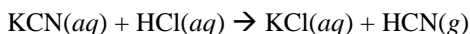
4.41 The annual production of sulfur dioxide from burning coal and fossil fuels, auto exhaust, and other sources is about 26 million tons. The equation for the reaction is



How much sulfur, present in the original materials, would result in that quantity of SO₂?

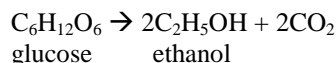
4.42 When baking soda (sodium bicarbonate or sodium hydrogen carbonate, NaHCO₃) is heated, it releases carbon dioxide gas, which is responsible for the rising of cookies, donuts, and bread. (a) Write a balanced equation for the decomposition of the compound (one of the products is Na₂CO₃). (b) Calculate the mass of NaHCO₃ required to produce 20.5 g of CO₂.

4.43 When potassium cyanide (KCN) reacts with acids, a deadly poisonous gas, hydrogen cyanide (HCN), is given off. Here is the equation:



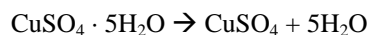
If a sample of 0.140 g of KCN is treated with an excess of HCl, calculate the amount of HCN formed, in grams.

4.44 Fermentation is a complex chemical process of wine making in which glucose is converted into ethanol and carbon dioxide:



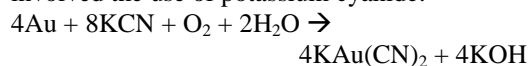
Starting with 500.4 g of glucose, what is the maximum amount of ethanol in grams and in liters that can be obtained by this process? (Density of ethanol = 0.789 g/mL.)

4.45 Each copper(II) sulfate unit is associated with five water molecules in crystalline copper(II) sulfate pentahydrate (CuSO₄ · 5H₂O). When this compound is heated in air above 100°C, it loses the water molecules and also its blue color:



If 9.60 g of CuSO₄ are left after heating 15.01 g of the blue compound, calculate the number of moles of H₂O originally present in the compound.

4.46 For many years the recovery of gold—that is, the separation of gold from other materials—involved the use of potassium cyanide:

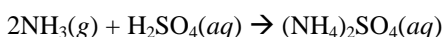


What is the minimum amount of KCN in moles needed to extract 29.0 g (about an ounce) of gold?

4.47 Limestone (CaCO₃) is decomposed by heating to quicklime (CaO) and carbon dioxide. Calculate how many grams of quicklime can be produced from 1.0 kg of limestone.

4.48 Nitrous oxide (N₂O) is also called “laughing gas.” It can be prepared by the thermal decomposition of ammonium nitrate (NH₄NO₃). The other product is H₂O. (a) Write a balanced equation for this reaction. (b) How many grams of N₂O are formed if 0.46 mole of NH₄NO₃ is used in the reaction?

4.49 The fertilizer ammonium sulfate $[(\text{NH}_4)_2\text{SO}_4]$ is prepared by the reaction between ammonia (NH_3) and sulfuric acid:



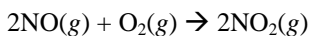
How many kilograms of NH_3 are needed to produce 1.00×10^5 kg of $(\text{NH}_4)_2\text{SO}_4$?

4.50 A common laboratory preparation of oxygen gas is the thermal decomposition of potassium chlorate (KClO_3). Assuming complete decomposition, calculate the number of grams of O_2 gas that can be obtained from 46.0 g of KClO_3 . (The products are KCl and O_2 .)

4.51 Define limiting reagent and excess reagent. What is the significance of the limiting reagent in predicting the amount of the product obtained in a reaction? Can there be a limiting reagent if only one reactant is present?

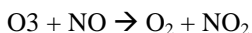
4.52 Give an everyday example that illustrates the limiting reagent concept.

4.53 Nitric oxide (NO) reacts with oxygen gas to form nitrogen dioxide (NO_2), a dark-brown gas:



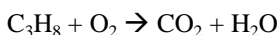
In one experiment 0.886 mole of NO is mixed with 0.503 mole of O_2 . Calculate which of the two reactants is the limiting reagent. Calculate also the number of moles of NO_2 produced.

4.54 The depletion of ozone (O_3) in the stratosphere has been a matter of great concern among scientists in recent years. It is believed that ozone can react with nitric oxide (NO) that is discharged from the high-altitude jet plane, the SST. The reaction is



If 0.740 g of O_3 reacts with 0.670 g of NO , how many grams of NO_2 will be produced? Which compound is the limiting reagent? Calculate the number of moles of the excess reagent remaining at the end of the reaction.

4.55 Propane (C_3H_8) is a component of natural gas and is used in domestic cooking and heating. (a) Balance the following equation representing the combustion of propane in air:



(b) How many grams of carbon dioxide can be produced by burning 3.65 moles of propane? Assume that oxygen is the excess reagent in this reaction.

4.56 Consider the reaction

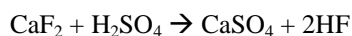


If 0.86 mole of MnO_2 and 48.2 g of HCl react, which reagent will be used up first? How many grams of Cl_2 will be produced?

4.57 Why is the yield of a reaction determined only by the amount of the limiting reagent?

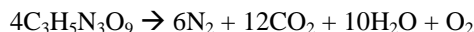
4.58 Why is the actual yield of a reaction almost always smaller than the theoretical yield?

4.59 Hydrogen fluoride is used in the manufacture of Freons (which destroy ozone in the stratosphere) and in the production of aluminum metal. It is prepared by the reaction



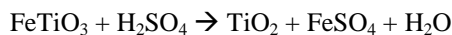
In one process 6.00 kg of CaF_2 are treated with an excess of H_2SO_4 and yield 2.86 kg of HF . Calculate the percent yield of HF .

4.60 Nitroglycerin ($\text{C}_3\text{H}_5\text{N}_3\text{O}_9$) is a powerful explosive. Its decomposition may be represented by



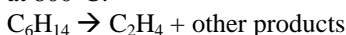
This reaction generates a large amount of heat and many gaseous products. It is the sudden formation of these gases, together with their rapid expansion, that produces the explosion. (a) What is the maximum amount of O_2 in grams that can be obtained from 2.00×10^2 g of nitroglycerin? (b) Calculate the percent yield in this reaction if the amount of O_2 generated is found to be 6.55 g.

4.61 Titanium(IV) oxide (TiO_2) is a white substance produced by the action of sulfuric acid on the mineral ilmenite (FeTiO_3):



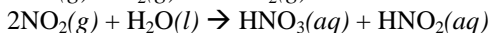
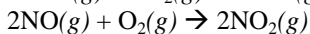
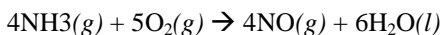
Its opaque and nontoxic properties make it suitable as a pigment in plastics and paints. In one process 8.00×10^3 kg of FeTiO_3 yielded 3.67×10^3 kg of TiO_2 . What is the percent yield of the reaction?

4.62 Ethylene (C_2H_4), an important industrial organic chemical, can be prepared by heating hexane (C_6H_{14}) at $800^\circ C$:



If the yield of ethylene production is 42.5 percent, what mass of hexane must be reacted to produce 481 g of ethylene?

4.63 Industrially, nitric acid is produced by the Ostwald process represented by the following equations:



What mass of NH_3 (in g) must be used to produce 1.00 ton of HNO_3 by the above procedure, assuming an 80 percent yield in each step? (1 ton = 2000 lb; 1 lb = 453.6 g.)

4.64 A sample of a compound of Cl and O reacts with an excess of H_2 to give 0.233 g of HCl and 0.403 g of H_2O . Determine the empirical formula of the compound.

4.65 How many moles of O are needed to combine with 0.212 mole of C to form (a) CO and (b) CO_2 ?

4.66 The aluminum sulfate hydrate $[Al_2(SO_4)_3 \cdot xH_2O]$ contains 8.20 percent Al by mass. Calculate x , that is, the number of water molecules associated with each $Al_2(SO_4)_3$ unit.

4.67 The carat is the unit of mass used by jewelers. One carat is exactly 200 mg. How many carbon atoms are present in a 24-carat diamond?

4.68 An iron bar weighed 664 g. After the bar had been standing in moist air for a month, exactly one-eighth of the iron turned to rust (Fe_2O_3). Calculate the final mass of the iron bar and rust.

4.69 Carbon dioxide (CO_2) is the gas that is mainly responsible for global warming (the greenhouse effect). The burning of fossil fuels is a major cause of the increased concentration of CO_2 in the atmosphere. Carbon dioxide is also the end product of metabolism (see Example 3.14). Using glucose as an example of food, calculate the annual human production of CO_2 in grams, assuming that each person

consumes 5.0×10^2 g of glucose per day. The world's population is 6.5 billion, and there are 365 days in a year.

4.70 Hemoglobin ($C_{2952}H_{4664}N_{812}O_{832}S_8Fe_4$) is the oxygen carrier in blood. (a) Calculate its molar mass. (b) An average adult has about 5.0 L of blood. Every milliliter of blood has approximately 5.0×10^9 erythrocytes, or red blood cells, and every red blood cell has about 2.8×10^8 hemoglobin molecules. Calculate the mass of hemoglobin molecules in grams in an average adult.

4.71 The natural abundances of the two stable isotopes of hydrogen (hydrogen and deuterium) are 1_1H : 99.985 percent and 2_1H : 0.015 percent. Assume that water exists as either H_2O or D_2O . Calculate the number of D_2O molecules in exactly 400 mL of water. (Density = 1.00 g/mL.)

4.72 Which of the following substances contains the greatest mass of chlorine? (a) 5.0 g Cl_2 , (b) 60.0 g $NaClO_3$, (c) 0.10 mol KCl, (d) 30.0 g $MgCl_2$, (e) 0.50 mol Cl_2 .

4.73 Potash is any potassium mineral that is used for its potassium content. Most of the potash produced in the United States goes into fertilizer. The major sources of potash are potassium chloride (KCl) and potassium sulfate (K_2SO_4). Potash production is often reported as the potassium oxide (K_2O) equivalent or the amount of K_2O that could be made from a given mineral. (a) If KCl costs \$0.055 per kg, for what price (dollar per kg) must K_2SO_4 be sold in order to supply the same amount of potassium on a per dollar basis? (b) What mass (in kg) of K_2O contains the same number of moles of K atoms as 1.00 kg of KCl?

4.74 The formula of a hydrate of barium chloride is $BaCl_2 \cdot xH_2O$. If 1.936 g of the compound gives 1.864 g of anhydrous $BaSO_4$ upon treatment with sulfuric acid, calculate the value of x .

4.75 It is estimated that the day Mt. St. Helens erupted (May 18, 1980), about 4.0×10^5 tons of SO_2 were released into the atmosphere. If all the SO_2 were eventually converted to sulfuric acid, how many tons of H_2SO_4 were produced?

4.76 Octane (C_8H_{18}) is a component of gasoline. Complete combustion of octane yields CO_2 and H_2O . Incomplete combustion produces CO and

H₂O, which not only reduces the efficiency of the engine using the fuel but is also toxic. In a certain test run, 1.000 gallon of octane is burned in an engine. The total mass of CO, CO₂, and H₂O produced is 11.53 kg. Calculate the efficiency of the process; that is, calculate the fraction of octane converted to CO₂. The density of octane is 2.650 kg/gallon.

4.77 Industrially, hydrogen gas can be prepared by reacting propane gas (C₃H₈) with steam at about 400°C. The products are carbon monoxide (CO) and hydrogen gas (H₂). (a) Write a balanced equation for the reaction. (b) How many kilograms of H₂ can be obtained from 2.84 × 10³ kg of propane?