Section 12.2 stoichiometric calculations answers

Skills to develop Explain the meaning of the term stoichiometry. Determine the relative quantities of each substance in chemical equations. You have learned that chemical equations give us information about the types of particles that react to form products. Chemical equations also give us the relative number of particles and moles that react to form products. In this section you will explore the quantitative relationships that exist between the quantities of reactants and products in a balanced equation. This is known as stoichiometry. Stoichiometry, by definition, is the calculation of the quantities of reactants or products in a chemical reaction using the relationships found in the balanced chemical equation. The word stoichiometry is actually Greek in two words: \(\sigma \tau \omicron \iota \eta \ota \omicron u \), which means element, and \(\mu \epsilon \tau \rho \omicron u), which means measure. The mole, as you remember, is a quantitative measure equivalent to The number of particles of Avogadro. So, what does that have to do with the chemical equation? Look at the chemical equation below. The coefficients used, after learning, tell us the relative amounts of each substance in the equation. So, for every 2 units of copper (II) sulphate (\(\ce{CuSO_4}\)) we need 4 units of potassium iodide (\(\ce{KI}\)). For every two dozen copper sulphates (II), we need 4 dozen potassium iodines. Since the mole unit is also a counting unit, we can interpret this equation in terms of moles, as well as: For every two copper moles (II) sulfate, we need 4 potassium iodide moles. The production of ammonia \(\left(\ce{NH_3} \right)\) from nitrogen and hydrogen gas is an important industrial reaction called the Haber process, according to German chemist Fritz Haber. \[\ce{N_2} \left(g \right) + 3 \ce{H_2} \left(g \right) \rightarrow 2 \ce{NH_3} \left(g \right)\] The balanced equation can be analyzed in several ways, as shown in the figure below. Figure \(\PageIndex{1}\): This representation of ammonia production from nitrogen and hydrogen presents several ways of interpreting the quantitative information of a chemical reaction. We see that a nitrogen molecule reacts with three hydrogen molecules to form two ammonia molecules. This is the smallest possible relative amount of reactants and products. In order to take into account higher relative amounts, each coefficient may be multiplied by the same number. For example, 10 nitrogen molecules would react with 30 hydrogen molecules to produce 20 ammonia molecules. The most useful quantity for particle counting is mole. So, if each coefficient is multiplied by a mole, the balanced chemical equation tells us that 1 nitrogen mole reacts by 3 hydrogen to produce 2 moles of ammonia. This is the conventional way to interpret any balanced chemical equation. Balanced. if each amount of mole is converted into grams by the use of molar mass, we can see that the law of mass preservation is followed. \(1 \: \ce{mol}\) of nitrogen has a mass of \(28.02 \: \text{g}\), while \(3 \: \text{mol}\) of hydrogen has a mass of \(6.06 \: \text{g}\) and \(2 \: \text{mol}\) of ammonia has a mass of \(34.08 \: \text{g}\). \[28.02 \: \text{g} \: \ce{N_2} + 6.06 \: \text{g} \: \ce{H_2} \rightarrow 34.08 \: \text{g} \: \ce{NH_3}\] Mass and number of atoms must be kept in any chemical reaction. The number of molecules is not necessarily preserved. Example \(\PageIndex{1}\) For burning the ethane (\ce{C_2H_6}\) the equation below, i \[2 \ce{C_2H_6} + 7 \ce{O_2} \rightarrow 4 \ce{CO_2} + 6 \ce{H_2O}\] Indicate the number of formula units or molecules in the balanced equation. Indicate the number of moles present in the balanced equation. SOLUTION Two molecules of \(\ce{C_2H_6}\ plus seven molecules of \(\ce{O_2}\) produce four molecules of \(\ce{CO_2}\) plus six molecules of \(\ce{H_2O}\). Two moles of \(\ce{C_2H_6}\) plus seven moles of \(\ce{O_2}\) produce four moles of \(\ce{CO_2}\) plus six moles of \(\ce{H_2O}\). Exercise \(\PageIndex{1}\) For the following equation below, indicate the number of units or molecules of the formula and the number of moles present in the balanced equation. \[\ce{KBrO_3} + 6 \ce{KI} + 6 \ce{HBr} \rightarrow 7 \ce{KBr} + 3 \ce{H_2O}\ Answer: One molecule of \(\ce{KBrO_3}\ ce{KI}\) plus six molecules of \(\ce{HBr}\) produces seven molecules of \(\ce{KBr}\) plus three molecules of \(\ce{I_2}\) and three molecules of \(\ce{H_2O}\). A mole of \(\ce{KBrO_3}\) plus six moles of \(\ce{KI}\) plus six moles of \(\ce{HBr}\) produces seven moles of \(\ce{KBr}\) plus three moles of \(\ce{I_2}\) plus three moles of \(\ce{H_2O}\). Summary stoichiometry is the calculation of the quantities of reactants or produced in a chemical reaction using the relationships found in the balanced chemical equation. The coefficients in a balanced chemical equation are the reaction ratios of the substances in the reaction. The coefficients of the balanced equation can be used to determine the ratio of moles to all substances in a reaction. Vocabulary Stoichiometry: Calculation of quantitative relationships of reactants and products in a balanced chemical equation. Unit of the formula: The empirical formula of an ion compound. Unit ratio: The ratio of the moles of a reagent or product to the moles of another reagent or product according to the coefficients of the balanced chemical equation. Taxpayers Because the consumption of alcoholic beverages negatively affects the performance of tasks that require skill and judgment, in most countries it is illegal to drive while under the influence of alcohol. In almost all U.S. states, a level of 0.08% by volume is considered legally legal Higher levels cause acute intoxication (0.20%), unconsciousness (approximately 0.30%), and even death (approximately 0.50%). Alcoometer is a portable device that measures the concentration of ethanol in a person's breathing, which is directly proportional to the level of alcohol in the blood. The reaction used in the alcoometer is ethanol oxidation by dichromate ion: \(3CH_3 CH_2 OH(aq) + \underset{yellow-orange}{2Cr_2 O_7^{2 -}}(aq) + 16H ^+ (aq) \underset{H_2 SO_4 (aq)}{\xrightarrow{\hspace{10px} Ag ^\hspace{1 00px }} 3CH_3 CO_2 H(aq) + \underset{green}{4Cr^{3+}} (aq) + 11H_2 O(l) \) When a measured volume (52.5 mL) of a suspect's breath is bubbled by a solution of excess potassium dichromate in diluted sulphuric acid, ethanol is rapidly absorbed and oxidized in acetic acid by dichromate ions. In this process, the chromium atoms in some of the Cr2O72− ions are reduced from Cr6+ to Cr3+. In the presence of Ag+ ions that act as a catalyst, the reaction is complete in less than one minute. Because The Cr2O72− ion (reactant) is orange-yellow and the Cr3+ ion (the product) forms a green solution, the amount of ethanol in the person's breath (limiting reaction) can be determined quite precisely by comparing the colour of the final solution with the colours of standard solutions prepared with known amounts of ethanol. A typical breathing amp contains 3.0 ml of a 0.25 mg/ml solution of K2Cr2O7 in 50% H2SO4, as well as a fixed concentration of AgNO3 (usually 0.25 mg/mL is used for this purpose). How many grams of ethanol must be present in a person's 52.5 ml breath to convert all Cr6+ to Cr3+? Date: volume and concentration of a reagent Requested: mass of another reagent required for the full reaction Strategy: A Calculate the number of moles of Cr2O72− ion in 1 ml of the alcoaxizer solution by dividing the mass K2Cr2O7 by the molar mass. B Find the total number of Cr2O72− ion moles in the alcoometer amp by multiplying the number of moles contained in 1 ml by the total volume of the alcootest solution (3.0 ml). C Use the mole ratios in the balanced chemical equation to calculate the number of C2H5OH moles required to fully react with the number of Cr2O72− ion moles present. Then find the required Mass of C2H5OH by multiplying the number of C2H5OH moles with the molar mass. Solution: A In any stoichiometry problem, the first step is always to calculate the number of moles of each reactant present. In this case, we are given the mass of K2Cr2O7 in 1 ml of solution, which we can use to calculate the number of k2Cr2O7 moles contained in 1 mL: \(\dfrac{alunite\: K_2 Cr_2 O_7} {1\: mL} = \dfrac{(0 .25\: \cancel{mg}\: K_2 Cr_2 O_7)} {mL} \left(\dfrac{dfrac{dfrac{dfrac{dfrac{dfrac{dfrac{dfrac{dfraf1\: \cancel{g}} {1000\: \right) \left(\dfrac{1\: mol} {294 .18\: \cancel{g}\: K_2 Cr_2 O_7} \right) = 8.5 \times 10 ^{-7}\: alunite \) \) table method 3CH3CH2OH(aq) + 2Cr2O72-(aq) 16H+(aq) → 3CH3CO2H(aq) 4Cr3+(aq) + 11H2O(l) Volume (mL) 3 mL Density (mg/ml) 0.25 mg/ml Mass 1.7 6 x 10-4 g 0.75 x 10-3 g MW 46.07 294.07 294.7 18 moles 3.82 x 10-6 2.55 x 10-6 Stoichiometric coefficients 3 2 16 3 4 11 Stoichiometric equivalents 1 ,27 x 10-6 1.1.27 x 10-6 1.1.27 x 10-6 1.1.27 x 10-6 1.1.27 x 10-6 1.1.11 Stoichiometric Equivalents 1.27 x 10-6 1.1.1.27 x 10-6 1.1.11 Stoichiometric equivalents 1.27 x 10-27 x 10-6 OR B Since 1 mole of K2Cr2O7 produces 1 mole of Cr2O72− when dissolved, each millilitre of solution contains 8.5 × 10−7 mol of Cr2O72−. The total number of moles of Cr2O72− in a 3.0 ml alcoometer amp is as follows \(moles\: Cr_2 O_7^{2-} = \left(\dfrac{8 .5 \times 10^{-7}\: mol} {1\: \cancel{mL} \right) (3 .0\: \cancel{mL}) = 2.6 \times 10^{-6}\: mol\: Cr_2 O_7^{2−} \) C Balanced chemical equation tells us that 3 mol of C2H5OH is necessary to consume 2 mol of Cr2O72− ion, so that the total number of C2H5OH moles required for full reaction is \(moles\: de\: C_2 H_5 OH = (2,6 \or 10 ^{-6}\: \cancel{mol\: Cr_2 O_7 ^{2-}}) \left(\dfrac{3\: mol\: C_2 H_5 OH} {2\: \cancel{mol\: Cr _2 O _7 ^{2 -}}} \right) = 3 .9 \times 10 ^{-6}\ : mol\: C _2 H _5 OH \) After indicated in the strategy, this number can be converted to the mass of C2H5OH using the molar mass: \(mass\: C _2 H _5 OH = (3 .9 \or 10 ^{-6}\: \cancel{mol\: C _2 H _5 OH}) \left(\df{046 .07\: g} {\cancel{mol\: C _2 H _5 OH}} \right) = 1.8 \times 10 ^{-4}\: g\: C _2 H _5 OH \) Thus, 1.8 × 10−4 g or 0.18 mg of C2H5OH should be present. Experimentally, it is found that this value corresponds to a blood alcohol level of 0.7%, which is usually fatal. Exercise Para-nitrophenol compound (molar mass = 139 g/mol) reacts with sodium hydroxide in aqueous solution to generate a yellow anion by reaction Since the amount of para-nitrophenol is easily estimated from the intensity of yellow color resulting when excess NaOH is added, reactions that produce para-nitrophenol are commonly used to measure the activity of enzymes, catalysts in biological systems. What volume of 0,105 M NaOH should be added to 50,0 ml of a solution containing 7,20 × 10−4 g of para-nitrophenol to ensure that the formation of yellow anion is complete? Answer: 4.93 × 10−5 L or 49.3 μL μL