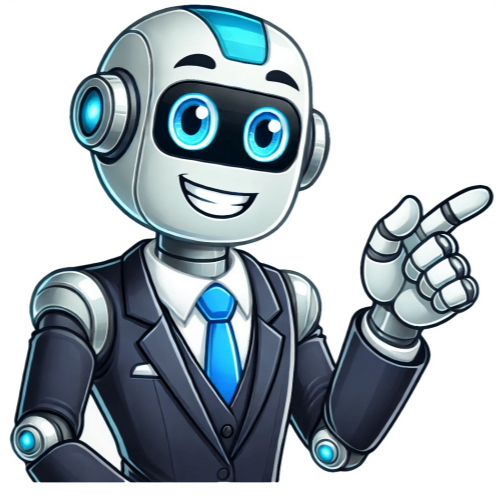


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Problem #11. The equation for the reduction of iron ore in a blast furnace is given below. (a) How many kilograms of iron can be produced by the reaction of 7.00 kg of Fe2O3 and 3.00 kg of CO? (b) How many kilograms of the excess reagent remains after reaction has ceased? Fe2O3 + 3CO → 2Fe + 3CO2 Solution to a: 1) Determine the limiting reagent. Fe2O3 → 7000 g / 159.687 g/mol = 43.836 molCO → 3000 g / 28.01 g/mol = 107.105 mol Fe2O3 → 43.836 mol / 1 mol = 43.836 mol → 107.105 mol / 3 mol = 35.702 mol CO is the limiting reagent. 2) Use the C to Fe molar ratio: 3 is to 2 as 107.105 mol is to x = 71.403 mol of Fe produced 3) Convert to kilograms of Fe: 71.403 mol (55.845 g/mol) = 3987.52 g to produce three sig figs this is 3.99 kg of iron Solution to b: 1) Use Fe2O3 to CO molar ratio 1 is to 3 as x is to 107.105 mol x = 35.702 mol of Fe2O3 consumed 2) Determine mass remaining: (35.703 mol) (159.687 g/mol) = 5.701 g = 1299 g to three sig figs, this is 1.30 kg Problem #12: The reaction of 4.25 g of Cl2 with 2.20 g of P4 produces 4.28 g of PCl5. What is the percent yield? Solution: 1) First, a balanced chemical equation: P4 + 10Cl2 → 4PCl5 2) Get moles, then limiting reagent: P4 → 2.20 g / 123.896 g/mol = 0.177568 molCl2 → 4.25 g / 70.906 g/mol = 0.599385 mol P4 → 0.177568 / 1 = 0.177568 mol → 0.599385 / 10 = 0.0599385 Cl2 is the limiting reagent. 3) How many grams of PCl5 are produced? Use Cl2 : PCl5 molar ratio 10 is to 4 (or 5 : 2, if you prefer) 5 is to 2 as 0.0599385 is to x = 0.239754 mol of PCl5 produced (0.239754 mol) (208.239 g/mol) = 4.99 g (to three sig figs) 4) Determine percent yield: (4.28 g / 4.99 g) x 100 = 85.8% Notice how asking about percent yield (oh, so innocuous!) forces you to go through an entire limiting reagent calculation first. Problem #13: 35.5 g SiO2 and 66.5 g of HF react to yield 45.8 g H2SiF6 in the following equation: SiO2(s) + 6HF(aq) → H2SiF6(aq) + 2H2O(l) (a) How much mass of the excess reactant remains after reaction ceases?(b) What is the theoretical yield of H2SiF6 in grams?(c) What is the percent yield? Solution to (a): 1) Must determine limiting reagent first (even is it not asked for in the question): SiO2 → 35.5 g / 60.084 g/mol = 0.59084 molHF → 66.5 g / 20.059 g/mol = 3.324 mol SiO2 → 0.59084 mol / 1 mol = 0.59084 molHF is limiting. 2) Determine how much SiO2 remains: The SiO2 : HF molar ratio is 1 : 6 is to 6 as x is to 3.324 mol x = 0.554 mol of SiO2 used up, 0.59084 mol - 0.554 mol = 0.03684 mol of SiO2 remains (0.03684 mol) (60.084 g/mol) = 2.21 g (to three sig figs) Solution to (b): There are 0.59084 mol of SiO2 SiO2 : H2SiF6 molar ratio is 1 : 1, therefore, 0.59084 mol of H2SiF6 produced (0.59084 mol) = 85.1 g (to three sig figs) Solution (c): (45.8 g / 85.1 g) (100) = 53.8% Problem #14: Gaseous ethane reacts with gaseous oxygen to produce gaseous carbon dioxide and gaseous water: (a) Suppose a chemist mixes 13.8 g of ethane and 45.8 g of oxygen. Calculate the theoretical yield of water. (b) Suppose the reaction actually produces 14.2 grams of water. Calculate the percent yield of water. Solution to (a): 1) Write the balanced equation: 2C2H6 + 7O2 → 4CO2 + 6H2O 2) Determine limiting reagent: C2H6 → 13.8 g / 30.0694 g/mol = 0.45894 molO2 → 45.8 g / 31.9988 g/mol = 1.4313 mol C2H6 → 0.45894 / 2 = 0.2294702 → 1.4313 / 7 = 0.20447 Oxygen is limiting. 3) Determine theoretical yield of water: The oxygen : water molar ratio is 7 : 6 is to 6 as 1.4313 mol is to x = 1.226828 mol of water 4) Convert moles of water to grams: (1.226828 mol) (18.015 g/mol) = 22.1 g (to three sig figs) Solution to (b): (14.2 g / 22.1 g) (100) = 64.2% Problem #15: A 0.972-g sample of a CaCl2 · 2H2O and K2C2O4 solid salt mixture is dissolved in 150 mL of deionized water, previously adjusted to a pH that is basic. The precipitate, after having been filtered and air-dried, has a mass of 0.375 g. The limiting reactant in the salt mixture was later determined to be CaCl2 2H2O (a) How many grams of the excess reactant, K2C2O4 H2O, reacted in the mixture? (b) What is the percent by mass of CaCl2 2H2O? (c) How many grams of the K2C2O4 H2O in the salt mixture remain unaffected? Solution to (a): 1) Write the balanced chemical reaction: CaCl2 + K2C2O4 → CaC2O4 + 2KCl 2) Determine moles of calcium oxalate that precipitated: 0.375 g / 128.096 g/mol = 0.0029275 mol 3) Determine moles, then grams of potassium oxalate: The K2C2O4 : CaC2O4 mole ratio is 1:1, therefore, 0.0029275 mol of potassium oxalate monohydrate reacted 0.0029275 mol (184.229 g/mol) = 0.53933 g To three sig figs, 0.539 g Solution to (b): 1) Determine moles, then grams of calcium chloride that reacted: The CaCl2 : CaC2O4 mole ratio is 1:1, therefore, 0.0029275 mol of calcium chloride reacted 0.0029275 mol (147.033 g/mol) = 0.43033 g To two sig figs, 0.43 g 4) Determine mass of calcium chloride: (0.430 g / 0.972 g/mol) = 44.24% Solution to (c): 1) Determine total mass that reacted: 0.430 g + 0.539 g = 0.969 g 2) Determine mass of H2O reacted: 0.972 g - 0.969 g = 0.003 g Remember, we're given only the total mass of the mixture, so we know the remainder is calcium chloride, since it has been determined by the limiting reagent. Problem #16: The reaction of 5.0 g C4H9OH, 22.4 g C4H9OH, 22.4 g C4H9OH, 17.1 g C4H9Br in the reaction below: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O Determine: (a) the theoretical yield of C4H9Br(b) the actual percent yield of C4H9Br(c) the masses of leftover reactants, if any Solution to (a): 1) Determine the limiting reagent between the first two reagents (the third reagent will be dealt with in step 2): C4H9OH → 5.0 g / 74.122 g/mol = 0.202369 molNaBr → 22.4 g / 102.894 g/mol = 0.217700 mol C4H9OH → 0.202369 / 1 = NaBr → 0.217700 / 1 = Between these two reactants, C4H9OH is limiting. 2) Compare C4H9OH to H2SO4 to determine which is limiting: C4H9OH → 0.202369 molH2SO4 → 32.7 g / 98.0768 g/mol = 0.333414 mol C4H9OH → 0.202369 / 1 = 0.202369 molH2SO4 → 0.333412 / 1 = 0.333412 Between these two reactants, C4H9OH is limiting. Overall, the above process shows that the limiting reagent for the entire reaction is C4H9OH. 3) Determine theoretical yield of C4H9Br: There is a 1:1 molar ratio between C4H9OH and C4H9Br. This means 0.202369 mol of C4H9Br is produced. (0.202369 mol) (137.019 g/mol) = 27.7 g (to three sig figs) Solution to (b): (17.1 g / 27.7 g) (100) = 61.7% Solution to (c): 1) Due to the 1:1 molar ratio: 0.202369 mol of NaBr is used up. 2) Therefore, 0.217700 0.202369 = 0.015331 mol of NaBr remains. The solution for sulfuric acid follows the same path as for NaBr. Conversion to grams is left to the reader. Problem #17: Ozonide (O3) reacts with nitric oxide (NO) discharged from jet planes to form oxygen gas and nitrogen dioxide. 0.740 g of ozone reacts with 0.670 g of nitric oxide. Determine the identity and quantity of the reactant supplied in excess. 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Solution: 1) First, the balanced equation: 14P4 + 32H2 → 4PH3 2) Determine moles of P4 and H2: 1.24 g / 123.896 g/mol = 0.01001 mol, 12 g / 2.016 g/mol = 0.059524 mol 3) Determine the limiting reagent: 0.01001 / 0.25 = 0.040044, 0.059524 / 1.5 = 0.396832 H2, by a nose! 4) Determine moles of PH3 that can be made from 0.059524 mol of H2: The molar ratio is 1.5 to 1.5 is to 1 as 0.059524 mol is to x = 0.039683 mol 5) Determine mass of PH3 that is the 100% yield amount: (0.039683 mol) (33.997 g/mol) = 1.35 g (to three sig figs) 6) Percent yield: (1.25 / 1.35) x 100 = 92.6% Problem #19: What mass of phosphorus (P4) is produced when 41.5 g of calcium phosphide, 26.5 g of silicon dioxide, and 7.80 g of carbon are reacted according to the equation: 2Ca3(PO4)2 + 6SiO2 + 10C → P4 + 6CaSiO3 + 10CO Solution: 1) Calculate the moles of each reactant: Ca3(PO4)2 → 41.5 g / 310.174 g/mol = 0.133796 molSiO2 → 26.5 g / 60.084 g/mol = 0.44105 molcarbon → 7.80 g / 12.011 g/mol = 0.649405 mol 2) We now write, for each reactant, the ratio of moles present to the coefficient: Ca3(PO4)2 → 0.133796 / 2 = 0.06689802 → 0.44105 / 6 = 0.07351carbon → 0.649405 / 10 = 0.0649405 3) Carbon is the limiting reagent. 4) Determine moles of P4 produced: The C to P4 molar ratio is 10 to 10 is to 1 as 0.0649405 is to x = 0.0649405 mol of P4 5) Determine mass of P4 produced: (0.0649405 mol) (123.896 g/mol) = 8.045866 g Using the rule for rounding with five, 8.04 g. Problem #20: 320 g of sulfur dioxide, 32 g of oxygen, and 64 g water react. (a) which reactant is the limiting reagent? (b) how much H2SO4 is produced? 2SO2 + O2 + 2H2O → 2H2SO4 Comment: I'm going to solve this problem by doing three mass-mass calculations using SO2, then O2, then H2O. The limiting reagent will be the one that produces the least amount of H2SO4. Solution to (a): 1) Determine moles of each reactant: SO2 → 320 g / 64.0638 g/mol = 4.9936 molO2 → 32 g / 32.00 g/mol = 1.0 molH2O → 64 g / 18.015 g/mol = 3.552 mol 2) Determine the limiting reagent: 4.9936 / 2 = 2.4968, 1.0 / 1 = 1.0, 3.552 / 2 = 1.776. O2 is the limiting reagent. 3) Determine the amount of H2SO4 produced: 1.0 mol O2 → 2.0 mol H2SO4 produced determine mass: (2.0 mol) (98 g/mol) = 196 g Solution using H2O: determine moles H2O → 64 g / 18 g/mol = 3.6 mol use 1:1 molar ratio to determine 3.6 mol of H2SO4 produced determine mass of H2SO4: (3.6 mol) (98 g/mol) = 353 g The final answer is that O2 is the limiting reagent and that 196 g of H2SO4 is produced. I copied this problem from an "answers" website. The answerer has a nice explanation on how to determine the limiting reagent. Here it is: Think of the coefficients as a "recipe" for the reaction. The "recipe" calls for 2 mol SO2, 1 mol O2, and 2 mol H2O. Convert each of the given masses into moles and find out how many "recipes" each substance can make. The substance that makes the fewest "recipes" is the limiting reagent. One "recipe" is: 2 mol SO2 = 2 x 64.1 g = 128 g 1 mol O2 = 32.0 g 2 mol H2O = 2 x 18.0 g = 36 g Determine "recipes": 320 g SO2 x (1 recipe / 128 g) = 2.50 recipes 32 g O2 x (1 recipe / 32.0 g) = 1.00 recipes 64 g H2O x (1 recipe / 36 g) = 1.78 recipes 32 g O2 is the limiting reagent because it makes the fewest "recipes." You would use the 32 g O2 to find the amount of H2SO4 produced. Problem #21: Consider the following reaction: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? Solution: 1) Write the balanced equation: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? 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One "recipe" is: 2 mol SO2 = 2 x 64.1 g = 128 g 1 mol O2 = 32.0 g 2 mol H2O = 2 x 18.0 g = 36 g Determine "recipes": 320 g SO2 x (1 recipe / 128 g) = 2.50 recipes 32 g O2 x (1 recipe / 32.0 g) = 1.00 recipes 64 g H2O x (1 recipe / 36 g) = 1.78 recipes 32 g O2 is the limiting reagent because it makes the fewest "recipes." You would use the 32 g O2 to find the amount of H2SO4 produced. Problem #21: Consider the following reaction: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? Solution: 1) Write the balanced equation: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? Solution: 1) The equation is balanced as written. 2) Determine moles of each reactant: C4H9OH → 15.0 g / 74.122 g/mol = 0.20237 molNaBr → 22.4 g / 102.894 g/mol = 0.2177 molH2SO4 → 22.4 g / 98.0768 g/mol = 0.3334 mol C4H9OH → 0.20237 / 1 = 0.20237 molH2SO4 → 0.3334 / 1 = 0.3334 Between these two reactants, C4H9OH is limiting. Overall, the above process shows that the limiting reagent for the entire reaction is C4H9OH. 3) Determine theoretical yield of C4H9Br: There is a 1:1 molar ratio between C4H9OH and C4H9Br. This means 0.202369 mol of C4H9Br is produced. (0.202369 mol) (137.019 g/mol) = 27.7 g (to three sig figs) Solution to (b): (17.1 g / 27.7 g) (100) = 61.7% Solution to (c): 1) Due to the 1:1 molar ratio: 0.202369 mol of NaBr is used up. 2) Therefore, 0.217700 0.202369 = 0.015331 mol of NaBr remains. The solution for sulfuric acid follows the same path as for NaBr. Conversion to grams is left to the reader. Problem #19: Ozonide (O3) reacts with nitric oxide (NO) discharged from jet planes to form oxygen gas and nitrogen dioxide. 0.740 g of ozone reacts with 0.670 g of nitric oxide. Determine the identity and quantity of the reactant supplied in excess. Solution: 1) Write the balanced chemical equation: NO + O3 → NO2 + O2 2) Determine moles: NO → 0.670 g / 30.006 g/mol = 0.22328 molO3 → 0.740 g / 44.987 g/mol = 0.0154176 mol 3) Determine limiting reagent: NO and O3 are in a 1:1 molar ratio O3 is limiting, making NO the compound in excess. 4) Determine quantity of excess reagent: Based on the 1:1 ratio, we need 0.0154176 mol of NO to use up. Therefore, 0.022328 mol - 0.0154176 mol = 0.0069114 mol of NO remaining Quantity remains: grams: (0.0069114 mol) (30.006 g/mol) = 0.207 g (to three significant figures) Problem #18: 1.24 g of P4 reacts with 12.0 g of H2 to give 12.5 g of PH3, determine percent yield. Solution: 1) First, the balanced equation: 14P4 + 32H2 → 4PH3 2) Determine moles of P4 and H2: 1.24 g / 123.896 g/mol = 0.01001 mol, 12 g / 2.016 g/mol = 0.059524 mol 3) Determine the limiting reagent: 0.01001 / 0.25 = 0.040044, 0.059524 / 1.5 = 0.396832 H2, by a nose! 4) Determine moles of PH3 that can be made from 0.059524 mol of H2: The molar ratio is 1.5 to 1.5 is to 1 as 0.059524 mol is to x = 0.039683 mol 5) Determine mass of PH3 that is the 100% yield amount: (0.039683 mol) (33.997 g/mol) = 1.35 g (to three sig figs) 6) Percent yield: (1.25 / 1.35) x 100 = 92.6% Problem #19: What mass of phosphorus (P4) is produced when 41.5 g of calcium phosphide, 26.5 g of silicon dioxide, and 7.80 g of carbon are reacted according to the equation: 2Ca3(PO4)2 + 6SiO2 + 10C → P4 + 6CaSiO3 + 10CO Solution: 1) Calculate the moles of each reactant: Ca3(PO4)2 → 41.5 g / 310.174 g/mol = 0.133796 molSiO2 → 26.5 g / 60.084 g/mol = 0.44105 molcarbon → 7.80 g / 12.011 g/mol = 0.649405 mol 2) We now write, for each reactant, the ratio of moles present to the coefficient: Ca3(PO4)2 → 0.133796 / 2 = 0.06689802 → 0.44105 / 6 = 0.07351carbon → 0.649405 / 10 = 0.0649405 3) Carbon is the limiting reagent. 4) Determine moles of P4 produced: The C to P4 molar ratio is 10 to 10 is to 1 as 0.0649405 is to x = 0.0649405 mol of P4 5) Determine mass of P4 produced: (0.0649405 mol) (123.896 g/mol) = 8.045866 g Using the rule for rounding with five, 8.04 g. Problem #20: 320 g of sulfur dioxide, 32 g of oxygen, and 64 g water react. (a) which reactant is the limiting reagent? (b) how much H2SO4 is produced? 2SO2 + O2 + 2H2O → 2H2SO4 Comment: I'm going to solve this problem by doing three mass-mass calculations using SO2, then O2, then H2O. The limiting reagent will be the one that produces the least amount of H2SO4. Solution to (a): 1) Determine moles of each reactant: SO2 → 320 g / 64.0638 g/mol = 4.9936 molO2 → 32 g / 32.00 g/mol = 1.0 molH2O → 64 g / 18.015 g/mol = 3.552 mol 2) Determine the limiting reagent: 4.9936 / 2 = 2.4968, 1.0 / 1 = 1.0, 3.552 / 2 = 1.776. O2 is the limiting reagent. 3) Determine the amount of H2SO4 produced: 1.0 mol O2 → 2.0 mol H2SO4 produced determine mass: (2.0 mol) (98 g/mol) = 196 g Solution using H2O: determine moles H2O → 64 g / 18 g/mol = 3.6 mol use 1:1 molar ratio to determine 3.6 mol of H2SO4 produced determine mass of H2SO4: (3.6 mol) (98 g/mol) = 353 g The final answer is that O2 is the limiting reagent and that 196 g of H2SO4 is produced. I copied this problem from an "answers" website. The answerer has a nice explanation on how to determine the limiting reagent. Here it is: Think of the coefficients as a "recipe" for the reaction. The "recipe" calls for 2 mol SO2, 1 mol O2, and 2 mol H2O. Convert each of the given masses into moles and find out how many "recipes" each substance can make. The substance that makes the fewest "recipes" is the limiting reagent. One "recipe" is: 2 mol SO2 = 2 x 64.1 g = 128 g 1 mol O2 = 32.0 g 2 mol H2O = 2 x 18.0 g = 36 g Determine "recipes": 320 g SO2 x (1 recipe / 128 g) = 2.50 recipes 32 g O2 x (1 recipe / 32.0 g) = 1.00 recipes 64 g H2O x (1 recipe / 36 g) = 1.78 recipes 32 g O2 is the limiting reagent because it makes the fewest "recipes." You would use the 32 g O2 to find the amount of H2SO4 produced. Problem #21: Consider the following reaction: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? Solution: 1) Write the balanced equation: C4H9OH + NaBr + H2SO4 → C4H9Br + NaHSO4 + H2O If 15.0 g of C4H9OH react with 22.4 g of NaBr and 22.4 g of H2SO4, what is the limiting reagent? 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