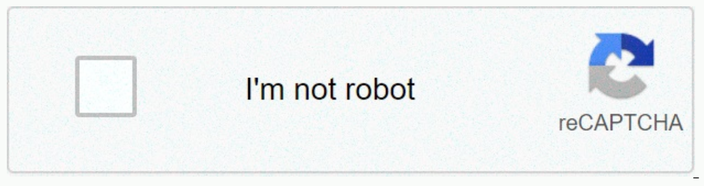

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.2 chemistry molecular formula worksheet answers

At the end of this section, you can: Calculate the percent composition of a compound Determining the empirical formula of a compound Determining the molecular formula of a compound The previous section discussed the relationship between the massive mass of a substance and the number of atoms or molecules it contains (moles). Given the chemical formula of the substance, you can determine the amount of the substance (moles) of its mass, and vice versa. But what happens if the chemical formula of a substance is unknown? In this section, these same principles will be applied to derive the chemical formulas of unknown substances from experimental mass measurements. The elemental composition of a compound defines its chemical identity, and chemical formulas are the most succinct way to represent this elementary makeup. When the formula of a compound is unknown, measuring the mass of each of its constituent elements is often the first step in the process of experimental determination of the formula. The results of these measurements allow the calculation of the percent composition of the compound, defined as the percentage by mass of each element in the compound. For example, consider a gas compound composed solely of carbon and hydrogen. The percent composition of this compound could be represented as follows: %H=mass Hmass composite×100%%H=mass composite Hmass×100% %C=massive cmass compound×1 00%C=massive cmass compound×100% If the analysis of a sample of 10.0 g of this gas showed that it contained 2.5 g H and 7.5 g C, the composition percent would be calculated at 25% H and 75% C : %H=2.5g H10.0g composite×100%=25%%H=2.5g H10.0g composite×100%=25% %C=7.5g C10.0g composite×100%=25% %C=7.5g C10. Composite 0g×100%=75%C=7.5g C10.0g composite×100%=75% Composition analysis calculation percent of a sample of 12.04 g of a carbon composite liquid compound, hydrogen, nitrogen showed that it contained 7.34 g C, 1.85 g H, and 2.85 g N. What is the percent composition of this compound? Solution to calculate the composition percent, divide the mass experimentally derived from each element by the overall mass of the compound, and then convert to a percentage: %C=7.34g Composite C12.04g×100%=61.0%H=1.85g H12.04 compoundg×100%=15.4%N=2.85g Composite N12.04g×100%=23.7%C=7.734g Composite C12.04g×100%=61.0%H=1.85g Composite H12.04g×100%=1 5.4%N=2.85g N12.04g composite×100%=23.7% Analysis results indicate that the compound is 61.0% C , 15.4% H, and 23.7% N en masse. Check your learning A sample of 24.81 g of a gaseous compound containing only carbon, oxygen and chlorine is determined to contain 3.01 g C, 4.00 g O and 17.81 g Cl. What is the percent composition of this compound? 12.1% C, 16.1% O, 71.8% Cl Percent Composition is also useful for evaluating the relative abundance of an element given in different compounds of known formulas. As an example, consider the ammonics that contain (NH3), ammonium ammonium (NH4NO3), and urea (CH4N2O). The nitrogen element is the active ingredient for agricultural purposes, so the massive percentage of nitrogen in the compound is a practical and economic concern for consumers choosing between these fertilizers. For these types of applications, the percent composition of a compound is easily derived from its mass of formula and the atomic masses of its constituent elements. An NH3 molecule contains an N atom weighing 14.01mu and three H-atoms weighing a total of (3 ×× 1,008 amu) = 3,024mu. La massa de fórmula d'amoníac és per tant (14.01 amu + 3.024 amu) = 17.03 amu, i la seva composició per cent és: %N=14.01amu N17.03amuNH3×100%=82.27%H=3.024amu H17.03amuNH3× 100%=17.76%%N=14.01amu N17.03amuNH3×100%=82.27%H=3.024amu H17.03NHamu3×100%=17.76% Aquest mateix enfocament es pot prendre tenint en compte un parell de molècules, una dotzena de molècules, o un talp de molècules, etc. The latter amount is more convenient and would simply involve the use of molar masses rather than atomic masses and formula, as Explain 3.10 demonstrated. While the molecular or empirical formula of the compound in question is known, the percent composition can be derived from the atomic masses or molars of the elements of the compound. Determining the composition percent from a molecular formula aspirin is a compound with the molecular formula C9H8O4. What is its percent composition? Solution To calculate the composition percent, the masses of C, H and O are needed in a known mass of C9H8O4. It is convenient to consider 1 mol of C9H8O4 and use its molar mass (180.159 g/mole, determined from the chemical formula) to calculate the percentages of each of its elements: %C=9mol C×molar mass Cmolar massC9H8O4×100=9×12.01g/mol180.159g/mol×100=108.09g/mol180.159g/mol×100%C=60.00%C%C=9mol C×molar mass Cmolar massC9H8O4×100=9×12.01g/mol180.159g/mol×100=108.09g/mol180.159g/mol×100%C=60.00%C%H=8mol H×molar mass Hmolar massC9H8O4×100=8×1.008g/mol180.159g/mol×100=8.064g/mol180.159g/mol×100%H=4.476%H%H=8mol H×molar mass Hmolar massC9H8O4×100=8×1.008g/mol180.159g/mol×100=8.064g/mol180.159g/mol×100%H=4.476%H%O=4mol O×molar mass Omolar massC9H8O4×100=4×16.00g/mol180.159g/mol×100=64.00g/mol180.159g/mol×100%O=35.52%%O=4mol O×molar mass Omolar massC9H8O4×100=4×16.00g/mol180.159g/mol×100=64.00g/mol180.159g/mol×100%O=35.52%Note that these percentages sum to equal 100.00% when appropriately rounded. Check your three-digit significant learning, what is the massive percentage of iron in the Fe2O3 compound? As mentioned above, the most common approach to determining a compound's chemical formula is to first measure the masses of its constituent elements. However, note that chemical formulas represent the relative numbers, not the masses, of atoms in the substance. Therefore, the data experimentally of the mass should be used to number of atoms in the compound. This is achieved by using molar masses to convert the mass of each element into a series of moles. These molar quantities are used to calculate the whole number proportions that can be used to derive the empirical formula from the substance. Consider a sample of compound determined to contain 1.71 g C and 0.287 g H. The corresponding numbers of atoms (in moles) are: 1.71g C×1mol C12.01g C=0.142mol C0.287g H×1mol H1.008g H=0.284mol H1.71g C ×1mol C12.01g C=0.142mol C0.287g H×1mol H1.008g H=0.284mol HThus, this compound can be represented by the formula C0.142H0.284. By convention, formulas contain integer subscript, which can be achieved by dividing each subscript by the smaller subscript: C0.1420.142H0.2840.142orCH2C0.1420 .142H0.2840.142orCH2 (Remember that the subscript 1 is not written but assumed if no other number is present.) The empirical formula of this compound is therefore CH2. This may or may not be the molecular formula of the compound as well; However, additional information is needed to make this determination (as discussed later in this section). Consider as another example a sample of compound determined to contain 5.31 g Cl and 8.40 g O. Following the same approach produces a provisional empirical formula of: C10.150O0.525=Cl0.1500.150O0.5250.150=ClO3.5C10.15 0O0.525=Cl0.1500.150O0.5250.150=ClO3.5Th this case, split by the smaller subscript still leaves us with a decimal subscript in the empirical formula. To convert this to an integer, multiply each of the subscript by two, retaining the same atom ratio and ceding Cl2O7 as the final empirical formula. In short, empirical formulas are derived from masses of elements experimentally measured by: Derive the number of moles of each element of its mass By dividing the molar quantity of each element by the smallest molar quantity to produce subscript for a provisional empirical formula Multiplying all coefficients by an integer, if necessary, to ensure that you get the smallest total number ratio of Subindex Figure 3.11 describes this procedure in the fashionable diagram flow for a substance containing elements A and X. Figure 3.11 The empirical formula of a compound can be derived from the masses of all elements of the sample. Determine the empirical formula of a compound from the masses of its elements A sample of black mineral hematite (Figure 3.12), an iron oxide found in many iron ores, contains 34.97 g of iron and 15.03 g of oxygen. What is the empirical formula of hematite? Figure 3.12 Hematite is an iron oxide used in jewelry. (credit: Mauro Cateb) Solution This problem provides the mass in grams of each element. Start by finding the moles of each: 34.97g Fe(mol Fe15.03g O(mol O16.00g)=0.939 4mol O34.97g Fe(mol Fe55.85g)=0.6261mol Fe15.03g O(mol O16.00g)=0.9394mol O Next, derive the iron-oxygen molar ratio divided by the mole number: 0.62610.6261=1.000mol Fe0.93940.6261=1.500mol O0.62610.6261 =1.000mol Fe0.93940.6261=1.500mol OThe ratio is 1,000 iron mole to 1,500 oxygen mole (Fe1O1.5). Finally, multiply the ratio by two to get the smallest possible total number while keeping the correct iron-oxygen ratio: 2 (Fe1O1.5)=Fe2O32(Fe1O1.5)=Fe2O3 The empirical formula is Fe2O3. Check your learning What is the empirical formula of a compound if a sample contains 0.130 g of nitrogen and 0.370 g of oxygen? For additional worked examples illustrating empirical formula bypass, watch the short video clip. Finally, with regard to the derivative of empirical formulas, we consider cases in which the percent composition of a compound is available instead of the absolute masses of the constituent elements of the compound. In these cases, the composition of the percentage can be used to calculate the masses of elements present in any convenient mass of compound; these masses can be used to derive empirical formula in the usual way. Determination of an empirical formula from the composition percent Bacterial fermentation of grain to produce ethanol forms a gas with a composition percent of 27.29% C and 72.71% O (Figure 3.13). What is the empirical formula of this gas? Figure 3.13 A carbon oxide is removed from these fermentation tanks through the large copper pipes on top. (credit: Dual Freq/Wikimedia Commons) Solution Since the scale for percentages is 100, it is more convenient to calculate the mass of elements present in a sample that weighs 100 g. The calculation is more convenient because, by definition for percent composition, the mass of an element given in grams is numerically equivalent to the percentage of mass of the element. This numerical equivalence is the result of the definition of the percentage unit, whose name derives from the Latin phrase percent that means by the hundred. Considering this definition, the mass percentages provided may be more conveniently expressed as fractions: 27.29%C=27.29g C100g compound72.71%O=72.71g O100g compound27.29%C=27.29g C100g compound72.71%O=72.71g O100g compound The molar amounts of carbon and oxygen in a 100-g sample are calculated by dividing each element's mass by its molar mass:27.29g C(mol C12.01g)=2.272mol C72.71g O(mol O16.00g)=4.544mol O27.29g C(mol C12.01g)=2.272mol C72.71g O(mol O16.00g)=4.544mol O Coefficients for the tentative empirical formula are derived by dividing each molar amount by the lesser of the two: 2.272mol C2.272=14.544mol O2.272=22.272mol C2.272=14.544mol O2.272=2 Since the resulting ratio is one carbon to two oxygen atoms, the empirical formula is CO2. Check your learning What is the empirical formula of a compound containing 40.0% C, 6.71% H, and 53.28% O? Remember that empirical formulas are representing the relative number of Determining the absolute number of atoms that make up a single molecule of a covalent compound requires knowledge of both its empirical formula and its molecular mass or molar mass. These quantities can be determined experimentally by various measurement techniques. Molecular mass, for example, is often derived from the compound's massive spectrum (see the discussion of this technique in the previous chapter on atoms and molecules). Molar mass can be measured by a series of experimental methods, many of which will be introduced in later chapters of this text. Molecular formulas are derived by comparing the molecular mass or molar of the compound with its mass of empirical formula. As the name suggests, an empirical formula mass is the sum of the average atomic masses of all atoms represented in an empirical formula. If the molecular mass (or molar) of the substance is known, it can be divided by the mass of empirical formula to produce the number of empirical formula units per molecule (n): molecular mass or molar (amu orgmol)empirical formula mass (amu org (amu orgmol)=nformula units/molecules of molar mass (amu orgmol)empirical formula mass(amu orgmol)=nformula units/molecule The molecular formula is obtained by multiplying each subscript in the empirical formula by n, as shown by the generic empirical formula AxBy: (AxBy)n=AnxBny(AxBy)n=Example AnxBnyFor, consider a covalent compound against empirical formula is determined to be CH2O. The empirical formula mass for this compound is about 30 amu (the sum of 12 amu for an atom C, 2 amu for two H atoms, and 16 amu for an Atom O). If the molecular mass of the compound is determined in 180 amu, this indicates that the molecules in this compound contain six times the number of atoms represented in the empirical formula: 180amu/molecule30amuformula unit=6formula units/molecule180amu/moleculea30amuformula unit=6formula units/molecules of this compounds are represented by molecular formulas whose subscript are six times larger than those in the empirical formula: (CH2O)6=C6H12O6(CH2O)6=C6H12O6 Note that this same approach can be used when using molar mass (g/mol) instead of molecular mass (amu). In this case, it is considered a mole of units of empirical formulas and molecules, unlike individual units and molecules. The determination of the Molecular Formula for Nicotine nicotine, an alkaloid in the nocturnal shade family of plants that is primarily responsible for the addictive nature of cigarettes, contains 74.02% C, 8.710% H, and 17.27% N. If 40.57 g of nicotine contains 0,2500 nicotine mole, what is the molecular formula? Solution Determining the molecular formula from the data provided will require the comparison of the formula mass from the compound to its molar mass. As a first step, use the percentage composition to derive the empirical formula from the compound. Supposing a convenient, a 100-g 100-g of nicotine yields the following molar amounts of its elements: (74.02g C)(1mol C12.01g C)=6.163mol C(8.710g H)(1mol H1.01g H)=8.624mol H(17.27g N)(1mol N14.01g N)=1.233mol N(74.02g C)(1mol C12.01g C)=6.163mol C(8.710g H)(1mol H1.01g H)=8.624mol H(17.27g N)(1mol N14.01g N)=1.233mol N Next, calculate the molar ratios of these elements relative to the least abundant element, N.6.163mol C/1.233 mol N=5 6.163mol C/1.233 mol N=5 8.264mol H/1.233 mol N=7 8.264mol H/1.233 mol N=71.233mol N/1.233 mol N=11.233mol N/1.233 mol N=11.2331.233 =1.000mol N 6.1631.233 =4.998mol C 8.6241.233=6.994mol H 1.2331.233 =1.000mol N 6.1631.233 =4.998mol C 8.6241.233=6.994mol H The C-to-N and H-to-N molar ratios are adequately close to whole numbers , i així la fórmula empírica és C5H7N. La massa de fórmula empírica per a aquest compost és, per tant, la unitat de fórmula 81.13 amu / formula, o 81.13 g / mol unitat de fórmula. Calculate the molar mass for nicotine from the given mass and molar amount of compound: 40.57g nicotine0.2500mol nicotine=162.3gmol40.57g nicotine0.2500mol nicotine=162.3gmol Comparing the molar mass and empirical formula mass indicates that each nicotine molecule contains two formula units: 162.3g/mol81.13gformula unit=2formula units/molecule162.3g/mol81.13gformula unit=2formula units/molecule Finally, derive the molecular formula for nicotine from the empirical formula by multiplying each subscript by two: (C5H7N)2=C10H14N2(C5H7N)2=C10H14N2Check Your Learning What is the molecular formula of a compound with a percent composition of 49.47% C, 5.201% H, 28.84% N, and 16.48% O, and a molecular mass of 194.2 amu? Amu?