Calculating Molarity

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1. Introduction

On August 9th, 1776, an Italian mathematician and physicist was born, only to present one of the most fundamental numbers of science: the mole. Also named after the discoverer's name, Avogadro's number is approximately 6.023×10^{23} of a substance. The mole is used as a unit in stoichiometry or the calculation of molarity from chemistry in which the amount of reactants and products of a chemical reaction is measured.

reactants $\longrightarrow$ products

Figure 1: The reactants of a chemical reaction are located on the left side of the arrow, while the products are located on the right.

Due to the involvement of elements in chemical reactions, which are expressed in amounts of atomic mass units (amu), such minute amounts of each element in a reaction would not be significant for applications in real life. As a result, the atomic mass of an element is converted into units of moles, which follows the rule that one moles of carbon-12 is equal to approximately 12 grams of carbon-12 [1]. Thus, one mole of a substance is equal to the atomic mass of the substance.

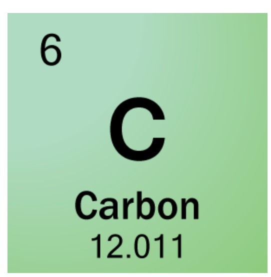

Figure 2: The atomic number (6), symbol (C), and atomic mass (12.011) is located at the top, center, and bottom, respectively.

2. Examples

Stoichiometric questions usually ask for the identification of a certain amount of element or compound when a specific amount of another compound is already given. The correct calculation of the result is necessary for the chemical reaction to take place.

An example question and chemical reaction shown in "Equation 1" will be used to go through each step of calculating morality: If we have 61 grams of Fe_2O_3, how many grams of Al do we need for the reaction to occur?

$$Fe_2O_3 + Al \rightarrow Fe + Al_2O_3 \quad (1)$$

a) Step 1: Balance the Equation

If the type and number of elements on the reactant side and the product side are not identical, chemical reactions will not be able to occur, because chemical reactions describe the conversion of a substance to another, not the transformation in the form of an element to another. The current equation is not balanced with two iron atoms, three oxygen atoms, and one aluminum atom as the reactants, and only one iron atom, three oxygen atoms, and two aluminum atoms.

Equations are balanced using the addition of coefficients in front of elements or compounds as shown in "Equation 2."

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3 \quad (2)$$

Adding the coefficient '2' in front of the reactant 'Al' and the product 'Fe,' the total number of reactants and products are equal with two iron atoms, three oxygen atoms, and two aluminum atoms on each side.

b) Step 2: Calculate the Mole Ratio

Balancing the equation by adding a coefficient is altering the molar ratio between what is given (Fe_2O_3) and what must be found (Al). This ratio of 'Al' in relation with 'Fe_2O_3' is shown in "Equation 3."

2 moles of Al/ 1 mole of Fe_2O_3 (3)

c) Step 3: Convert Mass into Moles

Since the atomic mass of each element and compound of the chemical reaction must be converted into moles, the atomic mass of iron, oxygen, and aluminum is needed and can be found in the periodic table.

One mole of iron is approximately 56 grams of iron when rounded to the nearest whole number, one mole of oxygen is 16 grams, and one mole aluminum is 27 grams. Of "Equation 1," 'Fe_2O_3' is made up of two iron atoms and three oxygen atoms, which results in 160 grams of 'Fe_2O_3' in one mole as shown in "Equation 4."

$$2(56) + 3(16) = 1\ mole\ of\ Fe_2O_3\ is\ 160\ grams \quad (4)$$

d) Step 4: Calculate the Number of Moles Given

Recall that the question is expecting an answer for the amount of 'Al' if 61 grams of 'Fe_2O_3' is given. The given number is significantly less than 160 grams of 'Fe_2O_3,' supporting the fact that 61 grams of the substance is less than one mole of 'Fe_2O_3.' To precisely determine the number of moles of the given substance, the given amount must be divided by one mole of the substance, which is illustrated in "Equation 5."

$$61\ grams\ of\ Fe_2O_3\ /\ 160\ grams\ of\ Fe_2O_3\ =\ 0.38\ moles\ of\ Fe_2O_3 \tag{5}$$

e) Step 5: Apply Moles to Mole Ratio

Recall from "Equation 3" that the mole ratio of 'Al' and 'Fe_2O_3' is '2.' This ratio should be applied to the number of moles given, which is '$0.38\ moles$' as shown in "Equation 5." The result is '$0.76\ moles$' of 'Al,' which is shown in "Equation 6."

$$0.38\ moles \times 2 = 0.76\ moles\ of\ Al \tag{6}$$

The number of moles of 'Al' can finally be converted into grams by multiplying the mass of 'Al,' which is 27 grams per mole, as displayed in "Equation 7."

$$0.76\ moles\ of\ Al \times 27\ grams\ =\ 20.52\ grams\ of\ Al \tag{7}$$

Consequently, 20.52 grams of aluminum is needed when 61 grams of 'Fe_2O_3' is given.

3. Applications

a) Science

i) Rocket Fuels

In order to gain successful reports from outer space, the machines that are used must be made up of the correct amount of reactants and products for take off and return. The RS-25 engines, which are fuels for rockets, are powered by liquid hydrogen and liquid oxygen [2]. However, if the correct amount of reactants and products are not used, the engine would not be able to support the rocket for further research. The chemical reaction of the RS-25 engine is a synthesis reaction of liquid hydrogen and oxygen, producing water and energy as shown in "Equation 8."

$$2H_2\ +\ O_2\ \rightarrow 2H_2O\ +\ Energy \tag{8}$$

ii) Aspirin

Stoichiometry and chemistry play a major role in creating suitable pharmaceutical products for people. A common example of stoichiometry in medicine is found in aspirin. Aspirin's functions as an anti-inflammatory and pain relief drug are only able to work in the presence of a correct amount of each element and compound on both the reactant and product side.

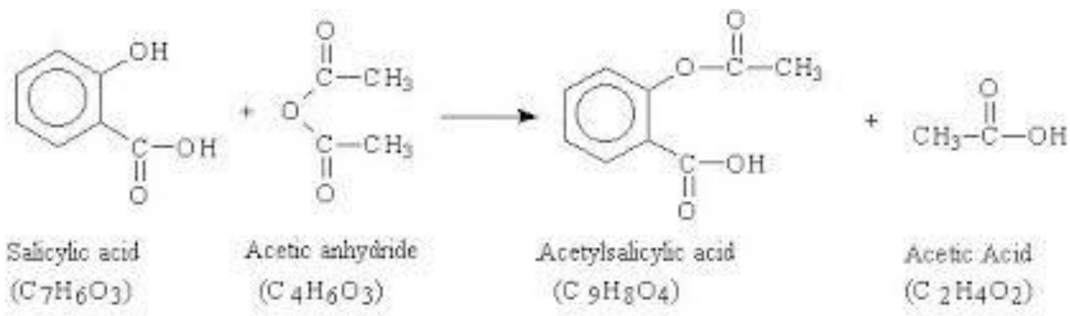

Figure 3: The chemical structures and formulas of the production of aspirin.

b) Household Products

i) Toothpaste

One of the many functions of toothpaste along with helping the gums avoid infections of disease and removing food in between teeth is preventing the teeth from decaying. Stannous fluoride (SnF_2) is added into the toothpaste mixture to maintain healthy teeth without decay. However, if the amount of stannous fluoride necessary for the correct results is exceeded due to miscalculations in stoichiometry, teeth could be stained in colour [3].

c) Food

Any recipe requires the application of calculating molarity, because cooking is chemistry. If a baker adds too much butter into cookie dough, the baked cookies will become too buttery and hard; on the other hand, if the dough needs more flour, the cookies would become too crispy and flat. Likewise, the correct amount of each ingredient to make a meal is important and possible with stoichiometry.

4. Conclusion

Although stoichiometry requires many steps of calculation and an understanding of the problem, the results give important numbers. These numbers are not only used in fields of science, but also in the production of commonly used objects, which make the concept so significant and highly applicable in daily lives.

5. References

[1] “Mole.” Encyclopaedia Britannica, https://www.britannica.com/science/mole-chemistry.

[2] Perry, Beverely. “Rocketology: NASA’s Space Launch System.” NASA Blogs, https://blogs.nasa.gov/Rocketology/tag/rocket-fuel/.

[3] “Why Stannous Fluoride?” Dentalcare.com, Crest, https://www.dentalcare.com/en-us/product/toothpaste/stannous-fluoride.