

Chapter 4 — Stoichiometry

2. Questions for Short Answers

1. Write down the chemical formula of barium nitride.

Ans: Barium forms the cation Ba^{2+} and nitrogen forms the anion N^{3-} . Applying the crisscross method, the numerical value of the charge on each ion becomes the subscript of the other ion: Ba_3N_2 . So, the chemical formula of barium nitride is Ba_3N_2 .

2. Find out the molecular formula of a compound whose empirical formula is CH_2O and its molar mass is 180.

Ans: Empirical formula mass of CH_2O = $12 + 2(1) + 16 = 30$. $n = \text{molar mass} \div \text{empirical formula mass} = 180 \div 30 = 6$. Molecular formula = $n(\text{empirical formula}) = (\text{CH}_2\text{O})_6 = \text{C}_6\text{H}_{12}\text{O}_6$. This compound is glucose.

3. How many molecules are present in 1.5 g H_2O ?

Ans: Molar mass of H_2O = $2(1) + 16 = 18 \text{ g mol}^{-1}$. Number of moles = $\text{mass} \div \text{molar mass} = 1.5 \div 18 = 0.0833 \text{ mol}$. Number of molecules = $\text{number of moles} \times \text{Avogadro's number} = 0.0833 \times 6.022 \times 10^{23} = 5.02 \times 10^{22} \text{ molecules}$.

4. What is the difference between a mole and Avogadro's number?

Ans: Avogadro's number ($N_A = 6.022 \times 10^{23}$) is simply a number — it is the number of units present in one mole of a substance, just as a dozen is the number 12. A mole, on the other hand, is the quantity or amount of a substance which contains Avogadro's number of particles, and the mass of one mole of a substance is called its molar mass and is expressed in grams. In short, Avogadro's number does the counting, while the mole is the amount being counted.

5. Write down the chemical equation of the following reaction: Copper + Sulphuric acid → Copper sulphate + Sulphur dioxide + Water

Ans: $\text{Cu(s)} + 2\text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{CuSO}_4(\text{aq}) + \text{SO}_2(\text{g}) + 2\text{H}_2\text{O(l)}$. The equation is balanced: there is 1 Cu, 2 S, 8 O and 4 H atoms on each side.

3. Constructed Response Questions

1. Different compounds will never have the same molecular formula but they can have the same empirical formula. Explain.

Ans: The molecular formula of a compound shows the actual number and the type of the different atoms present in one molecule of that compound, so it identifies the compound completely. The empirical formula, on the other hand, shows only the simplest whole number ratio of the atoms present; it does not tell us the actual number of atoms in the molecule. Since several different molecules can reduce to the same simple ratio, different compounds can share an empirical formula. For example, benzene (C_6H_6) and acetylene (C_2H_2) are quite different compounds but both have the empirical formula CH. For water the molecular and empirical formulas are the same, H_2O , because no simpler ratio exists between hydrogen and oxygen atoms in it.

2. Write down the chemical formulas of the following compounds: Calcium phosphate, Aluminium nitride, Sodium acetate, Ammonium carbonate and Bismuth sulphate.

Ans: Calcium phosphate: Ca^{2+} and PO_4^{3-} give $Ca_3(PO_4)_2$. Aluminium nitride: Al^{3+} and N^{3-} give AlN . Sodium acetate: Na^+ and CH_3COO^- give CH_3COONa . Ammonium carbonate: NH_4^+ and CO_3^{2-} give $(NH_4)_2CO_3$. Bismuth sulphate: Bi^{3+} and SO_4^{2-} give $Bi_2(SO_4)_3$.

3. Why does Avogadro's number have an immense importance in chemistry?

Ans: Atoms and molecules are so small that it is not possible to count them or to weigh them one by one. Avogadro's number links the mass of a substance in grams with the actual number of particles present in it, since $1.00\text{ g} = 6.022 \times 10^{23}\text{ amu}$. It therefore allows us to convert a balanced chemical equation, which gives only a ratio of atoms and molecules, into a ratio of masses in grams which can actually be weighed in the laboratory. For example, the equation $2C + O_2 \rightarrow 2CO$ becomes 24 g of carbon reacting with 32 g of oxygen to give 56 g of carbon monoxide. Without Avogadro's number these stoichiometric calculations would not be possible.

4. When 8.657 g of a compound were converted into elements, it gave 5.217 g of carbon, 0.962 g of hydrogen and 2.478 g of oxygen. Calculate the percentage of each element present in this compound.

Ans: Total mass of the compound = 8.657 g. Percentage of carbon = $(5.217 \div 8.657) \times 100 = 60.26\%$. Percentage of hydrogen = $(0.962 \div 8.657) \times 100 = 11.11\%$. Percentage of oxygen = $(2.478 \div 8.657) \times 100 = 28.62\%$. (The three percentages add up to 100%.)

5. How can you calculate the masses of the products formed in a reversible reaction?

Ans: A reversible reaction does not go to completion: the reactants react to give the products and the products, in turn, react to give the reactants back, until a state of equilibrium is reached. For this reason, the masses of the products cannot be calculated from the balanced chemical equation alone, as is done for an ordinary reaction. We must first find out experimentally how much of the reactant has actually been converted into products at equilibrium — that is, the actual amount reacted or the percentage yield. The mole ratio given by the balanced equation is then applied to that amount only, and the masses of the products actually formed are calculated from their molar masses.