

**Simple Step-by-Step
Guides to Solving
Chemistry Problems**

Mass, Moles and Number of Particles

Nigel Freestone
www.chemtextbook.com

Mass, Moles & Number of Particles

The **mole** links the mass of a substance to the number of **formula units** (particles – atoms, molecules) it contains. The mass of one mole of an element or compound is referred to as its **molar mass**, which is its **relative atomic mass** (A_r) or **relative formula mass** (M_r) in grams.

$$\text{Molar Mass } (M_r) = \text{Relative Formula Mass (RFM) in grams}$$

If you have m grams of a substance which has a molar mass of M_r , then the amount of a substance in moles, n , is given by:

$$\text{Molar Mass } (M_r) = \text{Mass } (m) / \text{Number of Moles } (n)$$

$$\text{Number of Moles } (n) = \text{Mass } (m) / \text{Molar Mass } (M_r)$$

$$\text{Number of Particles} = \text{Number of Moles } (n) \times 6.02 \times 10^{23}$$

If you know the values of any two of n , m or M_r , then you can calculate the third using one of the equations above.

Chemistry Calculating Frame for Moles, Mass and Number of Particles of Atoms & Molecules

The following simple calculating frame can be used to determine mass, number of moles, the number of particles and volume for elements and chemical compounds.

	Symbols	Equations	Given information	Calculated information
Chemical Formula	$X_a Y_b Z_c$			
Relative Formula Mass	M_r			
Mass	m	$n \times M_r$		
Number of Particles		$n \times 6.02 \times 10^{23}$		
Number of Moles	n	m/M_r		

Step 1: Construct a table based on the one above.

Step 2: Insert all given/known information in column 3.

Note: M_r can be determined using A_r values from the Periodic Table.

Step 3: Identify which parameter(s) that need to be calculated in column 3 using a question mark.

Step 4: Using the equations in column 2 and the information in column 3, calculate the unknown values and insert in column 4.

Example 1: How many moles of sodium hydrogen carbonatite (NaHCO_3) are present in 12 g of NaHCO_3 ?

Data from periodic table: $A_r[\text{Na}] = 23$; $A_r[\text{H}] = 1$; $A_r[\text{O}] = 16$

	Symbols	Equations	Given data	Calculated values
Formula	NaHCO ₃			
Relative Formula Mass	M _r			100
Mass (g)	m	n × M _r	12	
Number of Particles		n × 6.02 × 10 ²³		
Number of Moles	n	m/M _r	?	12/100 = 0.12
Volume (litre)	V	n × V _m		

Answer: 0.12 moles

Example 2: What is the mass of 0.25 moles of nitrogen dioxide (NO₂)?

Answer:

Data from periodic table: A_r[N] = 14; A_r[O] = 16

Relative Formula Mass (M_r) of NO₂ = 14 + (16 × 2) = 46

	Symbols	Equations	Given information	Calculated information
Formula	NO ₂			
Relative Formula Mass	M _r			46
Mass	m	n × M _r	?	0.25 × 46 = 11.5
Number of Particles		n × 6.02 × 10 ²³		
Number of Moles	n	m/M _r	0.25	

Answer: 11.5 g

Example 3: How many formula units are present in 1.25 × 10⁻³ moles of aluminium sulfate, Al₂(SO₄)₃?

Data from periodic table: A_r[Al] = 27; A_r[S] = 32; A_r[O] = 16

Relative Formula Mass (M_r) of Al₂(SO₄)₃ = (27 × 2) + (32 × 3) + (16 × 12) = 342

	Symbols	Equations	Given information	Calculated information
Formula	Al ₂ (SO ₄) ₃			
Relative Formula Mass	M _r			
Mass	M	n × M _r		
Number of Particles (formula units)		n × 6.02 × 10 ²³	?	1.25 × 10 ⁻³ × 6.02 × 10 ²³ = 7.525 × 10²⁰
Number of Moles	N	m/M _r	1.25 × 10 ⁻³	

Example 4: How many formula units of calcium chloride (CaCl₂) are present in 11 g of CaCl₂?

	Symbols	Equations	Given information	Calculated information
Formula	CaCl ₂			
Relative Formula Mass	M _r			111
Mass	M	n × M _r	11	

Number of Particles (formula units)		$n \times 6.02 \times 10^{23}$?	$0.1 \times 6.02 \times 10^{23}$ $= 6.02 \times 10^{22}$
Number of Moles	N	m/M _r	1.25×10^{-3}	$11/111 = 0.1$

Relative Formula Mass (M_r) of calcium chloride (CaCl₂) = 40 + (35.5 × 2) = 111

Number of moles (n) = mass / RFM = 11/111 = 0.1

Number of Formula Units = Number of Moles (n) × 6.02 × 10²³
 = 0.1 × 6.02 × 10²³
 = 6.02 × 10²²

Relative Formula Mass (M_r) of calcium chloride (CaCl₂) = 40 + (35.5 × 2) = 111

Number of moles (n) = mass / RFM
 = 11/111 = 0.1

Number of Formula Units = Number of Moles (n) × 6.02 × 10²³
 = 0.1 × 6.02 × 10²³ = 6.02 × 10²²



Practice Problems

1. How many moles of substance are present in the following?

- 5.30 g of sodium carbonate, Na₂CO₃
- 0.35 g of zinc nitrate, Zn(NO₃)₂
- 0.008 g of sodium hydroxide, NaOH
- 1.25 g of calcium carbonate, CaCO₃
- 3.5 g of benzene, C₆H₆
- 12 g of glucose, C₆H₁₂O₆
- 1 g of uranium dioxide, UO₂
- 0.3 g aluminium sulphate, Al₂(SO₄)₃
- 1.2 g iron (III) oxide, Fe₂O₃
- 3.4 g sulphur trioxide, SO₃

2. How many formula units are present in the following?

- 0.25 moles of Cl₂
- 5 moles of CO₂
- 10g of CaCO₃
- 2.45×10^{-3} moles of NH₃
- 0.34 kg of Fe₃O₄
- 2.56 moles of C₆H₆
- 1×10^{-6} g of Au
- 0.12 moles of CuSO₄
- 1 tonne of N₂
- 4.45×10^{-6} moles of (NH₄)₂CO₃

3. Determine the mass of the following:

- a. 2 moles of carbon dioxide, CO_2
- b. 0.01 moles of nitrogen dioxide, NO_2
- c. 1×10^{-5} moles of benzene, C_6H_6
- d. 2.03×10^{-3} moles of uranium dioxide, UO_2
- e. 1.12 moles of sulphuric acid, H_2SO_4
- f. 3×10^{-4} moles of calcium carbonate, CaCO_3
- g. 1.2 moles of ethane, C_2H_4
- h. 0.5 moles ethanoic acid, CH_3COOH
- i. 1.25×10^{-3} moles sodium hydroxide, NaOH
- j. 0.025 moles potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$

Answers are given on the next page.

Practice Problem Answers

I. How many moles of substance are present in the following?

Number of Moles = Mass/ M_r

a. 5.30 g of sodium carbonate, Na_2CO_3

Answer

$$M_r [\text{Na}(\text{CO}_3)_2] = 106 \text{ g mol}^{-1}$$

$$\text{Number of moles in 5.3 g of sodium carbonate} = \text{mass}/M_r = 5.3/106 = \mathbf{0.05}$$

b. 0.35 g of zinc nitrate, $\text{Zn}(\text{NO}_3)_2$

Answer

$$M_r [\text{Zn}(\text{NO}_3)_2] = 189 \text{ g mol}^{-1}$$

$$\text{Number of moles in 0.35 g of zinc nitrate} = \text{mass}/M_r = 0.35/189 = \mathbf{1.85 \times 10^{-3}}$$

c. 0.008 g of sodium hydroxide, NaOH

Answer

$$M_r [\text{NaOH}] = 40 \text{ g mol}^{-1}$$

$$\text{Number of moles in 0.008g of sodium hydroxide} = \text{mass}/M_r = 0.008/40 = \mathbf{2 \times 10^{-4}}$$

d. 1.25 g of calcium carbonate, CaCO_3

Answer

$$M_r [\text{CaCO}_3] = 100 \text{ g mol}^{-1}$$

$$\text{Number of moles in 1.25g of calcium carbonate} = \text{mass}/M_r = 1.25/100 = \mathbf{0.0125}$$

e. 3.5 g of benzene, C_6H_6

Answer

$$M_r [\text{C}_6\text{H}_6] = 78 \text{ g mol}^{-1}$$

$$\text{Number of moles of benzene in 3.5g} = \text{mass}/M_r = 3.5/78 = \mathbf{0.045}$$

f. 12 g of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$

Answer

$$M_r [\text{C}_6\text{H}_{12}\text{O}_6] = 180 \text{ g mol}^{-1}$$

$$\text{Number of moles in 12g of glucose} = \text{mass}/M_r = 12/180 = \mathbf{0.067}$$

g. 1g of uranium dioxide, UO_2

Answer

$$M_r [\text{UO}_2] = 270 \text{ g mol}^{-1}$$

$$\text{Number of moles in 1g of uranium dioxide} = \text{mass}/M_r = 1/270 = \mathbf{3.7 \times 10^{-3}}$$

h. 0.3 g aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3$

Answer

$$M_r [\text{Al}_2(\text{SO}_4)_3] = 342 \text{ g mol}^{-1}$$

$$\text{Number of moles in 0.3g aluminium sulphate} = \text{mass}/M_r = 0.3/342 = \mathbf{8.77 \times 10^{-4}}$$

i. 1.2 g iron (III) oxide, Fe_2O_3

Answer

$$M_r [\text{Fe}_2\text{O}_3] = 160 \text{ g mol}^{-1}$$

$$\text{Number of moles in 1.2 g iron (III) oxide} = \text{mass}/M_r = 1.2/160 = \mathbf{7.5 \times 10^{-3}}$$

j. 3.4 g sulphur trioxide, SO_3

Answer

$$M_r [\text{SO}_3] = 80 \text{ g mol}^{-1}$$

$$\text{Number of moles in 3.4 g sulphur trioxide, } \text{SO}_3 = \text{mass}/M_r = 3.4/80 = \mathbf{0.0425}$$

2. How many formula units are present in the following?

$$\text{Number of formula units} = \text{Number of moles} \times 6.02 \times 10^{23}$$

- a. 0.25 moles of
- Cl_2

Answer

$$\text{Number of molecules of } \text{Cl}_2 \text{ in 0.25 moles} = 0.25 \times 6.02 \times 10^{23} = \mathbf{1.51 \times 10^{23}}$$

- b. 5 moles of
- CO_2

Answer

$$\text{Number of molecules of } \text{CO}_2 \text{ in 5 moles} = 5 \times 6.02 \times 10^{23} = \mathbf{3.01 \times 10^{24}}$$

- c. 10g of
- CaCO_3

Answer

$$M_r[\text{CaCO}_3] = 100$$

$$\text{Number of moles in 10g of } \text{CaCO}_3 = \text{mass}/M_r = 10/100 = 0.1$$

$$\text{Number of formula units in 10 g of } \text{CaCO}_3 = 0.1 \times 6.02 \times 10^{23} = \mathbf{6.02 \times 10^{22}}$$

- d.
- 2.45×10^{-3}
- moles of
- NH_3

Answer

$$\text{Number of formula units (molecules) of } \text{NH}_3 \text{ in } 2.45 \times 10^{-3} \text{ moles} = 2.45 \times 10^{-3} \times 6.02 \times 10^{23} = \mathbf{1.48 \times 10^{21}}$$

- e. 0.34 kg of
- Fe_3O_4

Answer

$$M_r[\text{Fe}_3\text{O}_4] = 232$$

$$\text{Number of moles of } \text{Fe}_3\text{O}_4 \text{ in 340 g (0.34 kg)} = \text{mass}/M_r = 340/232 = 1.47$$

$$\text{Number of formula units in 0.24 kg of } \text{Fe}_3\text{O}_4 = 1.47 \times 6.02 \times 10^{23} = \mathbf{8.85 \times 10^{23}}$$

- f. 2.56 moles of
- C_6H_6

Answer

$$\text{Number of particles (molecules) in 2.56 moles of } \text{C}_6\text{H}_6 = 2.56 \times 6.02 \times 10^{23} = \mathbf{1.54 \times 10^{24}}$$

- g.
- 1×10^{-6}
- g of Au

Answer

$$\text{Number of moles of Au in } 1 \times 10^{-6} \text{ g} = 1 \times 10^{-6}/197 = 5.08 \times 10^{-9}$$

$$\text{Number of atoms of Au in } 1 \times 10^{-6} \text{ g} = 5.08 \times 10^{-9} \times 6.02 \times 10^{23} = \mathbf{3.06 \times 10^{15}}$$

- h. 0.12 moles of
- CuSO_4

Answer

$$\text{Number of formula units of } \text{CuSO}_4 \text{ in 0.12 moles} = 0.12 \times 6.02 \times 10^{23} = \mathbf{7.22 \times 10^{22}}$$

- i. 1 tonne of
- N_2

Answer

$$M_r[\text{N}_2] = 28$$

$$\text{Number of moles of } \text{N}_2 \text{ in 1000 g (1 tonne)} = 1000/28 = 35.7$$

$$\text{Number of formula units in 1 tonne } \text{N}_2 = 35.7 \times 6.02 \times 10^{23} = \mathbf{2.15 \times 10^{25}}$$

- j.
- 4.45×10^{-6}
- moles of
- $(\text{NH}_4)_2\text{CO}_3$

Answer

$$\text{Number of formula units in } 4.45 \times 10^{-6} \text{ moles of } (\text{NH}_4)_2\text{CO}_3 = 4.45 \times 10^{-6} \times 6.02 \times 10^{23} = \mathbf{2.68 \times 10^{18}}$$

3. Determine the mass of the following:

$$\text{Mass} = \text{Number of Moles} \times M_r$$

- a. 2 moles of carbon dioxide,
- CO_2

Answer

$$M_r[\text{CO}_2] = 44 \text{ g mol}^{-1}$$

$$\text{Mass of 2 moles of carbon dioxide} = \text{number of moles} \times M_r = 2 \times 44 = \mathbf{88 \text{ g}}$$

- b. 0.01 moles of nitrogen dioxide, NO_2

Answer

$$M_r [\text{NO}_2] = 46 \text{ g mol}^{-1}$$

$$\text{Mass of 0.01 moles of nitrogen dioxide} = \text{number of moles} \times M_r = 0.01 \times 46 = \mathbf{0.46 \text{ g}}$$

- c. 1×10^{-5} moles of benzene, C_6H_6

Answer

$$M_r [\text{C}_6\text{H}_6] = 78 \text{ g mol}^{-1}$$

$$\text{Mass of } 1 \times 10^{-5} \text{ moles of benzene} = \text{number of moles} \times M_r = 1 \times 10^{-5} \times 78 = \mathbf{7.8 \times 10^{-4} \text{ g}}$$

- d. 2.03×10^{-3} moles of uranium dioxide, UO_2

Answer

$$M_r [\text{UO}_2] = 270 \text{ g mol}^{-1}$$

$$\text{Mass of } 2.03 \times 10^{-3} \text{ moles of uranium dioxide} = \text{number of moles} \times M_r = 2.03 \times 10^{-3} \times 270 = \mathbf{0.55 \text{ g}}$$

- e. 1.12 moles of sulphuric acid, H_2SO_4

Answer

$$M_r [\text{H}_2\text{SO}_4] = 98 \text{ g mol}^{-1}$$

$$\text{Mass of 1.12 moles of sulfuric acid} = \text{number of moles} \times M_r = 1.12 \times 98 = \mathbf{109.76 \text{ g}}$$

- f. 3×10^{-4} moles of calcium carbonate, CaCO_3

Answer

$$M_r [\text{CaCO}_3] = 100 \text{ g mol}^{-1}$$

$$\text{Mass of } 3 \times 10^{-4} \text{ moles of calcium carbonate} = \text{number of moles} \times M_r = 3 \times 10^{-4} \times 100 = \mathbf{0.03 \text{ g}}$$

- g. 1.2 moles of ethane, C_2H_4

Answer

$$M_r [\text{C}_2\text{H}_4] = 28 \text{ g mol}^{-1}$$

$$\text{Mass of 1.2 moles of ethane} = \text{number of moles} \times M_r = 1.2 \times 28 = \mathbf{33.6 \text{ g}}$$

- h. 0.5 moles ethanoic acid, CH_3COOH

Answer

$$M_r [\text{CH}_3\text{COOH}] = 60 \text{ g mol}^{-1}$$

$$\text{Mass of 0.5 moles ethanoic acid} = \text{number of moles} \times M_r = 0.5 \times 60 = \mathbf{30 \text{ g}}$$

- i. 1.25×10^{-3} moles sodium hydroxide, NaOH

Answer

$$M_r [\text{NaOH}] = 40 \text{ g mol}^{-1}$$

$$\text{Mass of } 1.25 \times 10^{-3} \text{ moles of sodium hydroxide} = \text{number of moles} \times M_r = 1.25 \times 10^{-3} \times 40 = \mathbf{0.05 \text{ g}}$$

- j. 0.025 moles potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$

Answer

$$M_r [\text{K}_2\text{Cr}_2\text{O}_7] = 294 \text{ g mol}^{-1}$$

$$\text{Mass of 0.025 moles of potassium dichromate} = \text{number of moles} \times M_r = 0.025 \times 294 = \mathbf{7.35 \text{ g}}$$