



### Lesson Objectives

By the end of this lesson, you should be able to:

- Define a **mole** and explain its role in the measurement of matter.
- Explain the relationship between the mole and **Avogadro's** number.
- Determine the molar mass of a molecule from its chemical formula.

**Science Practice:** Perform math calculations to determine the number of particles in a given sample of a substance.



### Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

mole	the SI unit for the amount of a substance; the number of atoms in 12 g of <b>C-12</b> , which is $6.02 \times 10^{23}$
Avogadro's number	The number of units in a mole, <b><math>6.02 \times 10^{23}</math></b>
molar mass	The mass of 1 mole of substance, which is equal to the molecular or formula mass in <b>grams</b>

## Instruction

## Molar Masses

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## Lesson Question

How are scientists able to count the number of particles in matter?

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## The Chemist's Dozen

**Mole (mol):** the **SI** unit for the amount of a substance; the number of atoms in 12 g of C-12, or  $6.02 \times 10^{23}$

1 mole NaCl  
58.44 g

$6.02 \times 10^{23}$  formula units

1 mole H<sub>2</sub>O  
18.02 g

$6.02 \times 10^{23}$  molecules

1 mole Mg

**24.31** g

$6.02 \times 10^{23}$  atoms

## Avogadro's Number

**Avogadro's number:** the number of units in a mole,  $6.02 \times 10^{23}$

- Named after Amadeo **Avogadro**
  - Equal volumes of gases contain the same number of particles at the same temperature and **pressure**.
- Based on mass of carbon-12

## Instruction

## Molar Masses

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**How to Calculate Avogadro's Number**

One atom of carbon-12 has a mass of  $12.00 \text{ amu}$ . How many atoms of carbon-12 are in  $12.00 \text{ g}$ ?

- Set up calculation:

$$12.00 \text{ g C-12} \times \frac{1 \text{ amu}}{1.66 \times 10^{-24} \text{ g}} \times \frac{1 \text{ atom C-12}}{12.00 \text{ amu}}$$

- Cancel units and solve:

$$12.00 \text{ g C-12} \times \frac{1 \text{ amu}}{1.66 \times 10^{-24} \text{ g}} \times \frac{1 \text{ atom C-12}}{12.00 \text{ amu}} = 6.02 \times 10^{23} \text{ atoms C-12}$$

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**Molar Mass and Average Atomic Mass**

Chemists use the mole and Avogadro's  $6.02 \times 10^{23}$  to relate average atomic mass to molar mass.

- Periodic** table: average atomic mass, amu
- Molar mass**: the mass in grams of 1 mole of a substance

The molar mass of an element, in grams per **mole**, has the **same** value as the average atomic mass of the **element** in amu.

## Instruction

## Molar Masses

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**Molar Mass of a Compound**

What is the molar mass of sodium chloride ( $\text{NaCl}$ )?

- Identify the component elements and their average atomic masses.

atomic

	Average Atomic Mass (g)
Na	22.99
Cl	35.45

- Identify the number of atoms of each element in one unit.
  - NaCl: one atom Na, one atom Cl

**Molar Mass of a Compound**

- Calculate the mass of one unit.

$$1 \times 22.99$$

$$1 \times 35.45$$

$$58.44 \text{ amu}$$

- Convert from atomic mass units to grams per mole.

$$58.44 \text{ amu} = 58.44 \text{ gm/mol of NaCl}$$

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**Molar Mass of a Compound**

What is the molar mass of calcium chloride ( $\text{CaCl}_2$ )?

- Identify component elements and their **average** atomic masses.

	Average Atomic Mass (g)
Ca	40.08
Cl	35.45

- Identify the number of atoms of each element in one unit.
  - $\text{CaCl}_2$ : one atom **Ca**, two atoms Cl

**Molar Mass of a Compound**

- Calculate the mass of one unit.

$$1 \times 40.08 = 40.08$$

$$2 \times 35.45 = 70.90$$

$$\mathbf{110.98 \text{ amu}}$$

- Convert from atomic mass units to grams per mole.

$$110.98 \text{ amu} = 58.44 \text{ gm/mol of } \mathbf{\text{CaCl}_2}$$

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## Molar Masses

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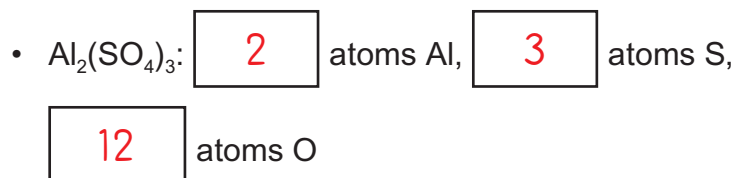
**Molar Mass of a Compound with Polyatomic Ions**

What is the molar mass of aluminum sulfate ( $\text{Al}_2(\text{SO}_4)_3$ )?

- Identify component elements and their average atomic masses.

	Average Atomic Mass (g)
Al	26.98
S	32.07
O	16.00

- Identify the number of atoms of each element in one unit.

**Molar Mass of a Compound with Polyatomic Ions**

- Calculate the mass of one unit.

$$2 \times 26.98 = 53.96$$

$$3 \times 32.07 = 96.21$$

$$12 \times 16.00 = 192.00$$

- Convert from atomic mass units to grams per mole.

$$342.17 \text{ amu} = 342.17 \text{ gm/mol of } \text{Al}_2(\text{SO}_4)_3$$

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### How to Calculate the Molar Mass of a Compound

- Identify component elements and their average atomic masses.
  - Use the average atomic mass from the periodic **table**.
- Identify the **number** of atoms of each element in 1 molecule or formula unit.
  - Use the chemical **formula**.
- Calculate the mass of 1 molecule or formula unit.
  - Add the average atomic masses.
  - Account for subscripts and parentheses.
- Convert from atomic mass units to grams per mole.
  - Molar mass in grams per mole = average atomic mass in atomic mass units.

## Instruction

## Molar Masses

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**How to Convert between Molar Mass and Number of Particles**

The molar mass of calcium sulfate ( $\text{CaSO}_4$ ) is  $136.15 \text{ g/mol}$ . How many formula units of  $\text{CaSO}_4$  are present in  $15.255 \text{ g}$ ?

- Set up the unit conversion.

$$15.255 \text{ g CaSO}_4 \times \frac{1 \text{ mol CaSO}_4}{136.15 \text{ g CaSO}_4} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

- Cancel units and solve.

$$15.255 \text{ g CaSO}_4 \times \frac{1 \text{ mol CaSO}_4}{136.15 \text{ g CaSO}_4} \times \frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 6.75 \times 10^{22} \text{ formula units CaSO}_4$$

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## Molar Masses

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**How to Convert between Molar Mass and Number of Particles**

The **molar** mass of water ( $\text{H}_2\text{O}$ ) is 18.02 g/mol. What is the mass of  $8.21 \times 10^{25}$  molecules of water?

- Set up the unit conversion.

$$8.21 \times 10^{25} \text{ molecules H}_2\text{O} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}}$$

- Cancel units and solve.

$$8.21 \times 10^{25} \text{ molecules H}_2\text{O} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 2.46 \times 10^3 \text{ g H}_2\text{O}$$

**How to Convert between Molar Mass and Number of Particles**

- Set up the unit **conversion**.
- Use molar mass to convert between mass and moles.
- Cancel **units** and solve.
- Make sure the desired units remain after cancellation.

## Summary

## Molar Masses

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## Lesson Question

How are scientists able to count the number of particles in matter?

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## Answer

(Sample answer) Moles are used to determine the number of particles present in matter. It is calculated from particles present in 12 g of carbon-12. The mass of one mole is known as molar mass and it has  $6.02 \times 10^{23}$  particles.

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## Avogadro's Number and the Mole

- Avogadro's number is the number of atoms, molecules, formula units, or other particles in 1 mole of a substance.
- Avogadro's number is equal to  $6.02 \times 10^{23}$ .
- Avogadro's number is based on the mass of **carbon-12**.
- One mole of any substance contains exactly the same number of atoms, molecules, or other particles as 1 **mole** of any other substance.
- The mole is useful in chemistry because it allows for direct comparisons of amounts.

# Summary | Molar Masses

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## Molar Mass and Conversions

- The molar mass of a substance is the mass in **grams** of 1 mole of particles of the substance.
- A substance's molar mass in grams has the same magnitude as the mass of one constituent particle in atomic mass units.
- The average atomic mass of an element given on the periodic table is equal to the element's molar mass.
- The molar mass of a **compound** can be calculated from the molar masses of its component elements.

*Use this space to write any questions or thoughts about this lesson.*