

- 1. Relative Atomic Mass
- 2. The Mole
- 3. Molar Mass

Relative Atomic Mass

Mass: The amount of matter in an object.

Atomic Mass:

- The mass of a particular atom.
- The atomic mass is found by comparing the mass of an element to the mass of an atom of carbon-12. Carbon-12 is assigned an atomic mass of exactly 12.00 u. *u = unified atomic mass unit.*
- The mass of one individual atom is extremely small. A large number of atoms is needed to provide enough mass to measure.
- A mole is...

The Mole

 THE MOLE

**Avogadro's Number**  
**1 mole =  $6.02214179 \times 10^{23}$  items**  
\*\*items = atoms/molecules/particles etc

The abbreviation for the unit mole is mol.

Think about the term "dozen".

We can say ...

- ... a **dozen** eggs = 12 eggs
- ... a **dozen** books = 12 books

Similarly, a **mole** of particles =  $6.02 \times 10^{23}$  particles  
... a mole of eggs =  $6.02 \times 10^{23}$  eggs

HOW BIG IS THE MOLE?

If you were able to count atoms at the rate of 10 million per second, it would take about 2 billion years to count the atoms in one mole.

If you had Avogadro's number of unpopped popcorn kernels, and spread them across the US, the country would be covered in popcorn to a depth of 9 miles.

One mole of seconds is about 19 quadrillion years, or 4 240 666 times the age of the Earth, or 954 150 times the age of the universe.

One mole of paper would make a stack that would reach to the moon more than 80 billion times.

One mole of donuts divided equally among Earth's people, each person would have 90 trillion donuts.

### Practice Problems:

1. How many lithium atoms are in 3.2 mol of lithium?

$$3.2 \text{ mol Li} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.9 \times 10^{24} \text{ Li atoms}$$

2. Find the number of chromium ions in 3.5 mol of chromium ions.

$$3.5 \text{ mol Cr} \times \frac{6.022 \times 10^{23} \text{ ions}}{1 \text{ mol}} = 2.1 \times 10^{24} \text{ Cr ions}$$

3. How many atoms are in 0.23 mol of NaCl?

$$0.23 \text{ mol NaCl} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \times \frac{2 \text{ atoms}}{1 \text{ molecule}} = 2.8 \times 10^{23} \text{ atoms of NaCl}$$

4.  $7.3 \times 10^{24}$  carbon monoxide molecules represent how many moles of carbon monoxide?

$$7.3 \times 10^{24} \text{ molecules CO} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 12 \text{ mol CO}$$

5. How many moles of argon do  $1.81 \times 10^{22}$  atoms of argon represent?

$$1.81 \times 10^{22} \text{ atoms Ar} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 0.0301 \text{ mol Ar}$$

$3.01 \times 10^{-2} \text{ mol Ar}$

6. How many hydrogen atoms are there in 1.0 mole of water? How many oxygen atoms are there in 1.0 mole of water? What is the ratio of hydrogen atoms to oxygen atoms?

$$1.0 \text{ mol H}_2\text{O} \times \frac{6.022 \times 10^{23} \text{ molecule}}{1 \text{ mol}} \times \frac{2 \text{ H atoms}}{1 \text{ molecule}} = 1.2 \times 10^{24} \text{ H atoms}$$

$$1.0 \text{ mol H}_2\text{O} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \times \frac{1 \text{ O atom}}{1 \text{ molecule}} = 6.022 \times 10^{23} \text{ atoms}$$

Ratio: 2 H to 1 O

Movie: How Big Is a Mole (<https://www.youtube.com/watch?v=TEI4jeETVmg>)

### Molar Mass

**Each element has a unique atomic mass.  
Each compound has a unique molecular mass.**

#### WHAT IS MOLECULAR MASS?

- The sum of the atomic mass of each element that makes up the compound.
- Unit = unified mass units (u)
- Example:
  - $\text{H}_2\text{O} = (2 \times \text{H}) + (1 \times \text{O})$   
 $= (2 \times 1.01) + (1 \times 16.00) = 18.02 \text{ u}$

#### WHAT IS MOLAR MASS?

- The molecular mass expressed in grams per mole.
- It is a conversion factor.

Example:

What is the molar mass of  $MgCl_2$ ?

- # of Mg atoms = 1
- Atomic mass of Mg = 24.31 g/mol
- # of Cl atoms = 2
- Atomic mass of Cl = 35.45 g/mol
  
- Molar mass =  
 $(1 \times 24.31) + (2 \times 35.45)$   
 $= 95.21 \text{ g/mol } MgCl_2$

Practice Problem I: (Find the Molar Mass)

7. What is the molar mass of  $Na_2Cr_2O_7$ ?

$$(2 \times 22.99) + (2 \times 52.00) + (7 \times 16.00)$$
$$= 261.98 \text{ g/mol } Na_2Cr_2O_7$$

8. What is the molar mass of iron (III) sulphide?  $Fe_2S_3$

$$(2 \times 55.85) + (3 \times 32.07)$$
$$= 207.91 \text{ g/mol } Fe_2S_3$$

9. What is the molar mass of ammonium nitrate?  $NH_4NO_3$

$$(2 \times 14.01) + (4 \times 1.01) + (3 \times 16.00)$$
$$= 80.06 \text{ g/mol } NH_4NO_3$$

10. What is the molar mass of propane,  $C_3H_8$ ?

$$(3 \times 12.01) + (8 \times 1.01)$$
$$= 44.11 \text{ g/mol } C_3H_8$$

What is the molar mass of  $Al_2(SO_4)_3$ ?

- # of Al atoms = 2
- Atomic mass of Al = 26.98 g/mol
- # of S atoms = 3
- Atomic mass of S = 32.07 g/mol
- # of O atoms = 12
- Atomic mass of O = 16.00 g/mol
  
- Molar mass =  
 $(2 \times 26.98) + (3 \times 32.07) + (12 \times 16.00)$   
 $= 342.17 \text{ g/mol } Al_2(SO_4)_3$

Compound	Formula	Molar Mass (g/mol)
a) $Na_2O$	---	61.98 g/mol
b) $Cu(NO_3)_2$	---	187.57 g/mol
c) Calcium chloride	$CaCl_2$	110.98 g/mol
d) Iron (II) oxide	$FeO$	71.85 g/mol
e) Iron (III) oxide	$Fe_2O_3$	159.70 g/mol
f) Copper (I) nitride	$Cu_3N$	204.66 g/mol
g) Potassium permanganate	$KMnO_4$	158.04 g/mol
h) $KBr$	---	119.00 g/mol
i) Nitrogen gas	$N_2$	28.02 g/mol
j) Argon gas	$Ar$	39.95 g/mol
k) $H_2SO_4$	---	98.09 g/mol

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g) 158.04 g/mol h) 119.00 g/mol i) 28.02 g/mol j) 39.95 g/mol k) 98.09 g/mol

**Practice Problem II: (Conversions + Molar Mass)**

11. Find the mass of 4.60 moles of  $\text{Ca}(\text{OH})_2$ .

$$(1 \times 40.08) + (2 \times 16.00) + (2 \times 17.01) = 74.10 \text{ g/mol } \text{Ca}(\text{OH})_2$$

$$4.60 \text{ mol } \text{Ca}(\text{OH})_2 \times \frac{74.10 \text{ g}}{1 \text{ mol}} = 340.86 \text{ g} = 341 \text{ g } \text{Ca}(\text{OH})_2$$

12. Calculate the number of moles present in a 358.0 gram sample of sodium carbonate.

$$\text{Na}_2\text{CO}_3 = 105.99 \text{ g/mol}$$

$$358.0 \text{ g } \text{Na}_2\text{CO}_3 \times \frac{1 \text{ mol}}{105.99 \text{ g}} = 3.378 \text{ mol } \text{Na}_2\text{CO}_3$$

13. How much would a sample of 7.4 mol of  $\text{MgO}$  weigh in kilograms?

$$\text{MgO} = 40.31 \text{ g/mol}$$

$$7.4 \text{ mol } \text{MgO} \times \frac{40.31 \text{ g}}{\text{mol}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.30 \text{ kg } \text{MgO}$$

14. A sample of  $\text{CoCl}_2$  weighs 4524 grams. How many mol of  $\text{CoCl}_2$  are in this sample?

$$\text{CoCl}_2 = 129.83 \text{ g/mol}$$

$$4524 \text{ g } \text{CoCl}_2 \times \frac{1 \text{ mol}}{129.83 \text{ g}} = 34.85 \text{ mol } \text{CoCl}_2$$

15. How many moles of water are in 1.8 g of water?  $\text{H}_2\text{O} = 18.02 \text{ g/mol}$

$$1.8 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 0.0998 \text{ mol} = 0.10 \text{ mol } \text{H}_2\text{O}$$

16. Very large quantities of chemicals are produced in the chemical industry. Worldwide production of sulphuric acid ( $\text{H}_2\text{SO}_4$ ) is estimated at two trillion ( $2.0 \times 10^{12}$ ) moles annually. How many tonnes of  $\text{H}_2\text{SO}_4$  is this? (1 tonne = 1000 kg)

$$\text{H}_2\text{SO}_4 = 98.09 \text{ g/mol}$$

$$2.0 \times 10^{12} \text{ mol} \times \frac{98.09 \text{ g}}{1 \text{ mol}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1 \text{ tonne}}{1000 \text{ kg}}$$

$$= 2.0 \times 10^8 \text{ tonnes } \text{H}_2\text{SO}_4$$

17. A mass of a 0.0150 mol sample of a gas that is known to have sulfur and oxygen has a mass of 0.9615g.

a) Find the molar mass of this gas.

$$\text{molar mass} = \frac{\text{g}}{\text{mol}} = \frac{0.9615\text{g}}{0.0150\text{mol}} = 64.1\text{g/mol}$$

b) Determine the molecular formula for this gas.

Write the formulae for several possible compounds of sulfur and oxygen, starting with the simplest.

Calculate the molar mass for each one and find which one matches with the calculated molar mass in (a).

Possible Formula for S & O	Molar Mass	Correct?
SO	48.07g/mol	No
SO <sub>2</sub>	64.07g/mol	Yes
S <sub>2</sub> O	80.14g/mol	No
SO <sub>3</sub>	80.07g/mol	No

The molecular formula for the compound is SO<sub>2</sub>.

18. How many molecules are in 200.0g of NaCl? NaCl = 58.44g/mol

$$200.0\text{g NaCl} \times \frac{1\text{ mol}}{58.44\text{g}} \times \frac{6.022 \times 10^{23}\text{ molecules}}{1\text{ mol}} = 2.061 \times 10^{24}\text{ molecules of NaCl}$$

19. How many atoms are in 2 molecules of Hg(IO<sub>3</sub>)<sub>2</sub>?

$$1 \times 2 \times 9 = 9$$

$$2\text{ molecules Hg(IO}_3)_2 \times \frac{9\text{ atoms}}{1\text{ molecule}} = 18\text{ atoms Hg(IO}_3)_2$$

20. How many molecules are in 64.0g of FeS? FeS = 87.92g/mol

$$64.0\text{g FeS} \times \frac{1\text{ mol}}{87.92\text{g}} \times \frac{6.022 \times 10^{23}\text{ molecules}}{1\text{ mol}} = 4.38 \times 10^{23}\text{ molecules FeS}$$

21. How many moles are in  $2.75 \times 10^{23}$  atoms of Fe?

$$2.75 \times 10^{23}\text{ atoms Fe} \times \frac{1\text{ mol}}{6.022 \times 10^{23}\text{ atoms}} = 0.457\text{ mol Fe}$$

22. What is the mass of  $3.00 \times 10^{22}$  atoms of Pt?

$$3.00 \times 10^{22} \text{ atoms Pt} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{195.08 \text{ g Pt}}{1 \text{ mol}} = 9.72 \text{ g Pt}$$

23. What is the density of acetic acid,  $\text{CH}_3\text{COOH}$ , if 0.250 mol has a volume of 14.3 mL? density = g/mL  
 $\text{CH}_3\text{COOH} = 60.02 \text{ g/mol}$

$$\frac{0.250 \text{ mol CH}_3\text{COOH}}{14.3 \text{ mL}} \times \frac{60.02 \text{ g}}{\text{mol}} = 1.05 \text{ g/mL CH}_3\text{COOH}$$

24. How many moles are in 85.0 mg of  $\text{CuSCN}$ ?

$$85.0 \text{ mg CuSCN} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol CuSCN}}{121.64 \text{ g CuSCN}} = 6.99 \times 10^{-4} \text{ mol CuSCN}$$

- 1)  $1.9 \times 10^{24}$  atoms
- 2)  $2.1 \times 10^{24}$  ions
- 3)  $2.8 \times 10^{23}$  atoms
- 4) 12 mol
- 5) 0.0301 mol
- 6)  $1.2 \times 10^{24}$  atoms,  $6.0 \times 10^{23}$  atoms, ratio is 2:1
- 7) 261.98 g/mol
- 8) 207.91 g/mol
- 9) 80.06 g/mol
- 10) 44.11 g/mol
- 11) 341g
- 12) 3.378 mol
- 13) 0.30 kg
- 14) 34.85 mol
- 15) 0.10 mol
- 16)  $2.0 \times 10^8$  tonnes
- 17) 64.1 g/mol,  $\text{SO}_2$
- 18)  $2.061 \times 10^{24}$  molecules
- 19) 18 atoms
- 20)  $4.38 \times 10^{23}$  molecules
- 21) 0.457 moles
- 22) 9.72g
- 23) 1.05g/mL
- 24)  $6.99 \times 10^{-4}$  mol

