

The Mole and Stoichiometry



The Mole:

- the basic unit of measurement in chemistry
- unit used to group particles (atoms, molecules)

ex. 1 pair = 2

1 dozen = 12

1 mole = 6.03×10^{23} particles

a.k.a. Avogadro's Number (N_A)

- a HUGE number!!!!!!

1 mol \$ = each person on Earth gets 200 000 billion \$

1 mol peas = 250 planets the size of Earth, 1m deep

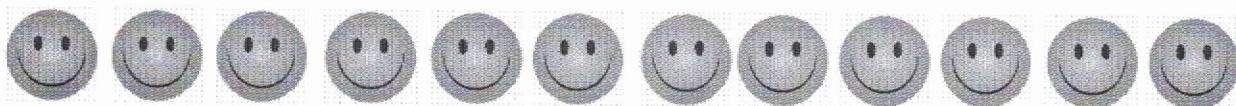
1 mol blood cells = > all blood cells in all humans on Earth

1 mol sand = all sand on Miami Beach

1 mol inches = 8 round trips of the galaxy

since the universe has been created... not even 1 mol of seconds has gone by!

- equal to mass of 12.0g of C₁₂



How many happy faces? 12 (a dozen)

How many smiles? 12



How many eyes? 24 (2x12)



examples

$$1 \text{ mol Mg} = 6.023 \times 10^{23} \text{ atoms of Mg}$$

$$1 \text{ mol Au} = 6.023 \times 10^{23} \text{ atoms of Au}$$

$$1 \text{ mol O}_2 = 6.023 \times 10^{23} \text{ molecules of O}_2$$

$$= 2 \times (6.023 \times 10^{23}) \text{ atoms of O}_2$$



$$2 \text{ mol Fe} = 2 \times (6.023 \times 10^{23}) \text{ atoms of Fe}$$

$$3 \text{ mol Cl}_2 = 3 \times (6.023 \times 10^{23}) \text{ molecules of Cl}_2$$

$$1 \text{ mol H}_2\text{O} = 2 \text{ mol of hydrogen atoms} + 1 \text{ mol oxygen atoms}$$

$$= 6.023 \times 10^{23} \text{ molecules of H}_2\text{O}$$

$$= 2 \times (6.023 \times 10^{23}) \text{ atoms of hydrogen}$$

$$= 6.023 \times 10^{23} \text{ atoms of oxygen}$$

Molar Mass

- 1 mol of table salt???
- definition: the mass of 1 mol of atoms of that element
- unit: g/mol
- where do I find it? The Periodic Table!

element	C	N	I
amount	1 mol	1 mol	1 mol
# particles	6.023×10^{23}	6.023×10^{23}	6.023×10^{23}
atomic mass	12.01 amu	14.01 amu	126.90 amu
molar mass	12.01g	14.01g	126.90g

donuts	eggs	friends
1 dozen	1 dozen	1 dozen
12	12	12
mass	is	different

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you'll soon ~~know~~ some
of these by heart.

* The periodic
table is our best
friend!

Calculating molar mass of compounds

- add up molar masses of each individual atoms

examples:

1) calcium carbonate (CaCO_3)

$$40.08 + 12.01 + 3(16.00) = \boxed{100.09 \text{ g/mol}}$$

2) zinc chloride (ZnCl_2)

$$65.39 + 2(35.45) = \boxed{136.29 \text{ g/mol}}$$

3) aluminum hydroxide (Al(OH)_3)

$$26.98 + 3(16.00) + 3(1.0) = \boxed{78.01 \text{ g/mol}}$$

4) 2.0 moles of H_2O

$$2(1.01) + 16.00 = 18.02 \text{ g/mol} \times 2 = \boxed{36.04 \text{ g}}$$

Calculating # moles using molar mass

examples

- 1) How many moles of fluorine atoms are present in 3.8g of fluorine?

$$3.8 \text{ g F} \times \frac{1 \text{ mol F}}{19.00 \text{ g F}} = \boxed{0.2 \text{ mol F}}$$

- 2) a) How many moles of water are in 100.0mL of water?

$\downarrow \text{H}_2\text{O}$
 $(1.01 + 16.00)$

$$100.0 \text{ mL H}_2\text{O} = 100.0 \text{ g H}_2\text{O} * \text{since H}_2\text{O has a density of } 1 \text{ g/mL}$$

$$100.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = \boxed{5.549 \text{ mol H}_2\text{O}}$$

- b) How many molecules of water are present? (in 100.0 mL H₂O)

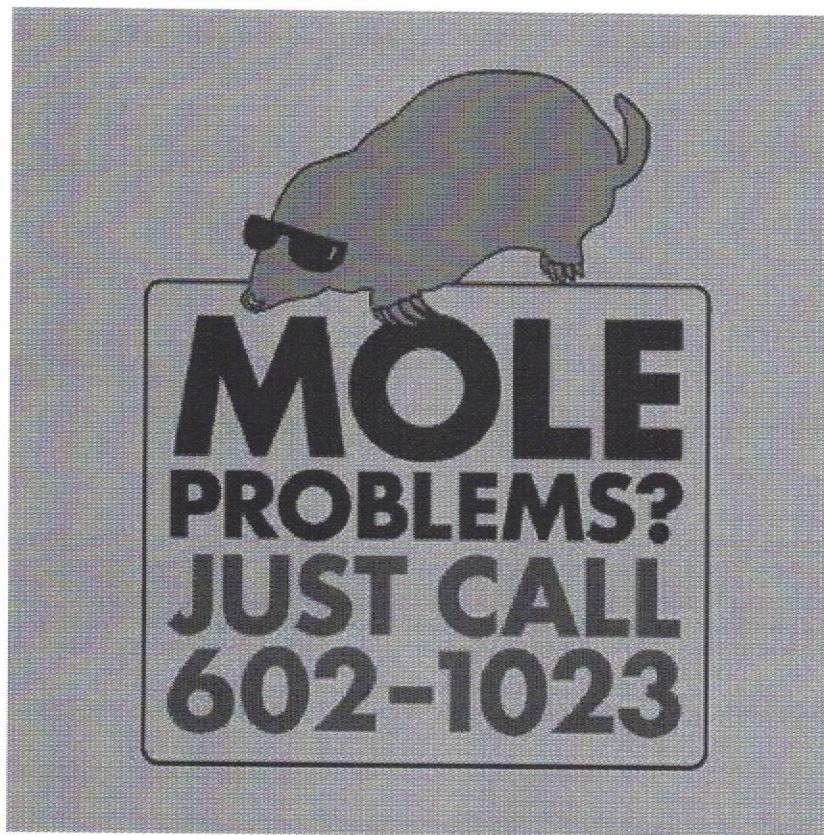
$$100.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{6.02 \times 10^{23} \text{ molecules H}_2\text{O}}{1 \text{ mol H}_2\text{O}} =$$

$\boxed{3.341 \text{ molecules of H}_2\text{O}}$

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Don't peek....fill out this table then check your answers.

compound	# mols	# molecules	# atoms	molar mass (g/mol)
HCl	1	6.023×10^{23}	$2 (6.023 \times 10^{23})$	$1.01 + 35.45 = 36.46$
K	1	-----	6.023×10^{23}	39.10
NaOH	1	6.023×10^{23}	$3 (6.023 \times 10^{23})$	$22.99 + 16.00 + 1.01 = 40.00$
H_3PO_4	1	6.023×10^{23}	$8 (6.023 \times 10^{23})$	$3(1.01) + 30.97 + 4(16.00) = 98.00$
$\text{Mg}(\text{OH})_2$	1	6.023×10^{23}	$5 (6.023 \times 10^{23})$	$24.31 + 2(16.00) + 2(1.01) = 58.33$



Molar concentration

- mol/L aka M (molarity)
- solution problems are like "regular" problems but with one extra step (using moles)

examples:

A) Finding grams

1. How much solute is needed to make 500.0ml of a 6.0mol/L KCl solution?

2 steps:

- #1) looking for mass start with concentration

$$\frac{6.0 \text{ mol}}{1000 \text{ ml}} \rightarrow \frac{x \text{ mol}}{500.0 \text{ ml}} \rightarrow \boxed{3 \text{ mol}}$$

- #2) use the moles!

$$\frac{54.45 \text{ g KCl}}{1 \text{ mol KCl}} \rightarrow \frac{x \text{ g KCl}}{3 \text{ mol KCl}} \rightarrow \boxed{163.35 \text{ g KCl}}$$

KCl
 39.00 + 35.45 } 54.45 g

B) Finding Molarity

2. What is the molar concentration of 4.0L of sodium hydroxide (NaOH) solution that is made of 120g of NaOH?

2 steps:

$$\begin{array}{r} \text{Na} - 22.99 \\ \text{O} - 16.00 \\ \text{H} - 1.01 \end{array} \left. \right\} 40.00 \text{ g}$$

- #1) looking for concentration start with mass

$$\frac{1 \text{ mol NaOH}}{40.00 \text{ g NaOH}} : \frac{x \text{ mol NaOH}}{120 \text{ g NaOH}} \Rightarrow \boxed{3 \text{ mol NaOH}}$$

- #2) use the moles!

$$\frac{3 \text{ mol NaOH}}{4.0 \text{ L NaOH}} : \frac{x \text{ mol NaOH}}{1.0 \text{ L NaOH}} \Rightarrow \boxed{0.75 \text{ mol/L}}$$

Always find moles first!

more examples: molar concentration

looking for grams ∵ start with concentration

3. What mass of solute is required to make 200.0mL of HCl at a concentration of 2.00mol/L? $\rightarrow 1.01 \rightarrow 35.45 \quad \{ \quad 36.46 \text{ g/mol.}$

$$\textcircled{1} \quad \frac{2.00 \text{ mol HCl}}{1000 \text{ ml HCl}} : \frac{x \text{ mol HCl}}{200.0 \text{ ml HCl}} \rightarrow 0.4 \text{ mol HCl}$$

$$\textcircled{2} \quad \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} : \frac{x \text{ g HCl}}{0.4 \text{ mol HCl}} \rightarrow \boxed{14.584 \text{ g HCl}} \\ \downarrow \\ \boxed{14.6 \text{ g (3 sig fig)}}$$

Looking for concentration, start with mass.

4. What is the molar concentration of 500.0mL of an NaCl solution prepared with 232g of NaCl?

$$22.99 + 35.45 = 58.44 \text{ g/mol}$$

find mol/L

$$\textcircled{1} \quad \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} : \frac{x \text{ mol NaCl}}{232 \text{ g NaCl}} \rightarrow 3.97 \text{ mol NaCl}$$

$$\textcircled{2} \quad \frac{3.97 \text{ mol NaCl}}{500.0 \text{ ml NaCl}} : \frac{x \text{ mol NaCl}}{1000 \text{ ml NaCl}} \rightarrow \boxed{7.94 \text{ mol / L}}$$

* using dimensional analysis *

→ better, easier way to do this

↳ you'll be using this in Physics all the time.

more examples: molar concentration

3. What mass of solute is required to make
200.0mL of HCl at a concentration of
2.00mol/L?

$$\frac{2.00 \text{ mol}}{1000 \text{ mL}}$$

$$200.0 \text{ mL HCl} \rightarrow 1.01 + 35.45 = 36.46 \text{ g/mol}$$

- start with # that's not a fraction

$$200.0 \text{ mL HCl} \times \frac{2.00 \text{ mol HCl}}{1000 \text{ mL HCl}} \times \frac{36.46 \text{ g/mol}}{1 \text{ mol HCl}} = 14.584 \text{ g HCl}$$



The # in the problem with the least # of sig figs is 2.00 mol/L

3 sig figs

$$\therefore 14.584 \text{ g} \rightarrow \boxed{14.6 \text{ g}}$$

→ This is the same as what's shown on the previous page, however both ratios are done in 1 line, all at once.

→ It's easier to know what to do next using dimensional analysis

4. What is the molar concentration of

500.0mL of an NaCl solution prepared with
232g of NaCl?

→ find mol/L
this needs to be done in 2 steps though.
 $22.99 + 35.45 = 58.44 \text{ g/mol}$

$$1. 232 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} \rightarrow 3.97 \text{ mol NaCl}$$

$$2. \frac{3.97 \text{ mol NaCl}}{500 \text{ mL NaCl}} \times \frac{1 \text{ mol NaCl}}{1000 \text{ mL NaCl}} \rightarrow \boxed{7.94 \text{ mol/L}}$$

Making a Solution

3.6 mol/L

$$22.99 + 19.00 = 41.99 \text{ g/mol}$$

#1) How would you prepare 250.0mL of a 3.6M solution of NaF?

1) Calculate mass of NaF needed.

$$\textcircled{1} \quad \frac{3.6 \text{ mol NaF}}{1000 \text{ mL NaF}} : \frac{x \text{ mol NaF}}{250.0 \text{ mL NaF}} \rightarrow 0.9 \text{ mol NaF}$$

 $\textcircled{2}$

$$\frac{41.99 \text{ g NaF}}{1 \text{ mol NaF}} : \frac{x \text{ g NaF}}{0.9 \text{ mol NaF}} \rightarrow 37.791 \text{ g NaF}$$

2) Mass 38g of NaF

* 38 since you need 2 sig figs

3) Put solute in a 250mL flask

4) Fill bulb of flask half-way up with water

5) Swirl to dissolve solute

6) Add water up to 250mL mark

7) Mix

$$24.31 + 32.07 + 4(16.00) = 120.38 \text{ g/mol}$$

#2) How would you prepare 5.0L of a 2.0M solution of MgSO_4 ?

2.0 mol/L

1) Calculate mass of MgSO_4 needed.

$$\textcircled{1} \quad \frac{2.0 \text{ mol MgSO}_4}{1 \text{ L MgSO}_4} : \frac{x \text{ mol MgSO}_4}{5.0 \text{ L MgSO}_4} \rightarrow 10 \text{ mol MgSO}_4$$

 $\textcircled{2}$

$$\frac{120.38 \text{ g MgSO}_4}{1 \text{ mol MgSO}_4} : \frac{x \text{ g MgSO}_4}{10 \text{ mol MgSO}_4} \rightarrow 1203.8 \text{ g MgSO}_4$$

2) → 7) as above

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