AP Chem 3.1 - 3.4 Notes - The Mole

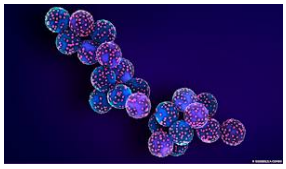
3.1 – 3.4 - The Mole

Counting Particles

Chemistry is all about particles: atoms, electrons, molecules, ions, formula units (representative particle composed of ions), or whatever you want to count.

To calculate particles, chemists use a unit called a "mole" (mol).

1 mole = 6.02 E 23 particles.
It equals the number of atoms in 12.0 grams of C-12.



Weird particles to count

Avogadro's Number

6.02 E 23 is also called Avogadro's Number, after Amedeo Avogadro, an Italian Physicist in the early 1800's.
Here's what he looked like:

Brief History Lesson

It's worth noting how Avogadro's Number was determined to be 6.02 E 23 particles.

In the mid to late 1800s, as atomic theory was widely accepted, scientists realized the need to define a number of particles with respect to a standard mass.

It was realized that hydrogen was the lightest element, so arbitrarily, Avogadro's Number was assigned to be the number of hydrogen atoms needed to have a mass exactly 1.00 grams.

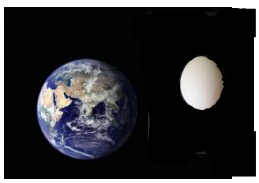
Later, with the discovery of isotopes, the definition was refined to be the number of particles in 12.000 grams of carbon - 12.

1. Conversions

A. How many eggs are in a dozen? 12
B. How many in three dozen? 36
C. Half a dozen? 6
D. A mole? 6.02 E 23
E. Two moles? 1.204 E 24 (or 12.04 E 23)

FYI: Two moles of eggs would have a volume roughly 1/9 that of the Earth!

Egg-Planet!



Conversions Process

1. Determine what your given information is.
2. Determine what you are seeking (solving for).
3. A. If going from moles to particles, use the following template: $$x.xx\,moles \bullet \frac{6.02\,E\,23\,particles}{1.0\,mol} = particles$$
3. B. If going from particles to moles, use: $$x.xx\,particles \bullet \frac{1\,mol}{6.02\,E\,23\,particles} = moles$$

Calculator Review: Exponent Key = EE

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2. Moles to Particles Example

How many atoms are there in 3.5 moles of zinc?

Known: 3.5 moles Zn.

Seeking: atoms of zinc. Which Equation do you use?

$$x.xx\,moles \bullet \frac{6.02\,E\,23\,particles}{1.0\,mol} = particles$$

$$3.5\ \cancel{mol\ Zn} \bullet \frac{6.02E23\,atoms}{1\,\cancel{mol\ Zn}} = 2.1E\ 24\,atoms\ Zn$$

3. Particles to Moles Example

It works the other way also.

How many moles of phosphorus are there in 1.5 E 23 atoms of phosphorus?

Known: 1.5 E 23 atoms phosphorus.

Seeking: moles phosphorus. Which Equation?

$$x.xx\ particles \bullet \frac{1mol}{6.02\,E\,23\,particles} = moles$$

$$1.5\,E23\,atoms\,P \bullet \frac{1.0\,mol}{6.02\,E\,23\,atoms} = 0.25\,mol\,P$$

4. Molar Mass

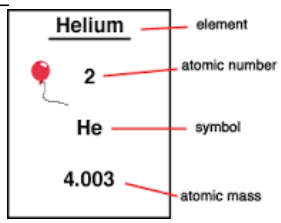
The periodic table shows the mass of one mole of each element.

A. What's the molar mass of aluminum?

26.98 grams/mol (round to hundredths place)

B. What's the molar mass of atomic iodine?

126.90 grams/mol



Conversions Process

Chemists use molar mass in conversions a lot.

1. Determine what information you're given, and what you are seeking.
2. Determine the molar mass of your element or compound.
3. A. If given an amount of moles, convert to mass:

$$x.xx\,mol \bullet \frac{x.xx\,g\,element}{1\,mol\,element} = grams\,element$$

(Moles of Sample) (Molar Mass (g/mol)) (Mass of Sample)

3. B. If given a mass, convert to moles:

$$x.xx\ g \bullet \frac{1\ mol\ element}{x.xx\ g\ element} = moles\ element$$

(Mass of Sample) (Molar Mass (mol/g)) (Moles of Sample)

5. Manganese Example

How many grams is in 3.00 moles of manganese?

Mn molar mass = 54.94 g/mol Mn

$$3.00\ \cancel{mol\ Mn} \bullet \frac{54.94\,g}{1\,\cancel{mol\ Mn}} = 165\,g\ Mn$$

3 sig. figs.

6. Calcium Example

How many moles are there in 70.50 g of calcium?

Ca molar mass = 40.08 g/mol Ca

We are looking for moles, so we must use:

$$\frac{1\,mole\,Ca}{40.08\,g\,Ca}$$

$$70.50\ \cancel{g\,Ca} \bullet \frac{1\,mole\,Ca}{40.08\ \cancel{g\,Ca}} = 1.76\,mol\,Ca$$

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Multiphasic Conversions

Mass converts to particles (and vice versa): use moles as an intermediate step.

You still need to determine your given information.

Then: mass to particles:

$$x.xx\ g \bullet \frac{1\ mole\ element}{x.xx\ g\ element} \bullet \frac{6.02\ E\ 23\ particles}{1\ mole} = particles$$

(Mass of Sample) (Molar Mass (mol/g)) (Particles Per mole) (Particles in Sample)

Or: particles to mass:

$$x.xx\ particles \bullet \frac{1\ mol}{6.02\ E\ 23\ particles} \bullet \frac{x.xx\ g\ element}{1\ mol\ element} = grams$$

(Particles in Sample) (Moles per Particle) (Molar Mass (g/mol)) (Mass of Sample)

7. Sulfur Example

How many atoms in 15.0 grams of sulfur?
Known: mass = 15.0 g S;
molar mass S = 32.07 g/mol S

Mass to particles:

$$15.0\ g\ S \bullet \frac{1\ mole\ S}{32.07\ g\ S} \bullet \frac{6.02\ E\ 23\ atoms\ S}{1\ mole\ S} = 2.82\ E\ 23\ atoms\ S$$

8. Gold Example

How many grams in 2.12 E 24 atoms of gold?
Known: quantity Au = 2.12 E 24 atoms;
molar mass of Au = 196.97 g/mol
Setup: particles to mass.

$$2.12\ E\ 24\ atoms\ Au \bullet \frac{1\ mol\ Au}{6.02\ E\ 23\ atoms} \bullet \frac{196.97\ g\ Au}{1\ mol\ Au} = 694\ g\ Au$$

3 sig. figs

Wow!
That IS what I'm talking about

Molar Mass Process

To determine a compound's molar mass:
1. Assume that you have one mole of compound.
2. List each element in the compound, as well as how many moles of each element is in the compound.
3. Multiply the moles of each element by that element's molar mass (in grams).
4. Add all the masses together. (Units = g/mol)

9. Molar Mass Guided Practice

Formulas tell how many moles of each element there are in on mole of compound.

How many moles of each element are there in calcium bicarbonate: $Ca(HCO_3)_2$?

Mole Inventory:
Ca = 1 mole
H = 2 moles
C = 2 moles
O = 6 moles

Stalactites in a cave

9. Molar Mass Calculation

What is the molar mass of $Ca(HCO_3)_2$:

Mole inventory:

Ca: $1\ mol\ Ca \bullet \frac{40.08\ g\ Ca}{mol\ Ca} = 40.08\ g\ Ca$

H: $2\ mol\ H \bullet \frac{1.01\ g\ H}{mol\ H} = 2.02\ g\ H$

C: $2\ mol\ C \bullet \frac{12.01\ g\ C}{mol\ C} = 24.02\ g\ C$

O: $6\ mol\ O \bullet \frac{16.00\ g\ O}{mol\ O} = 96.00\ g\ O$

Sum individual masses to find molar mass:
162.12 g/mol $Ca(HCO_3)_2$.

10. Water Example

Find the molar mass of water.

Formula = H_2O

Molar inventory:

H: $2\,mol\,H \bullet \frac{1.01\,g\,H}{mol\,H} = 2.02\,g\,H$

O: $1\,mol\,O \bullet \frac{16.00\,g\,O}{mol\,O} = 16.00\,g\,O$

Sum of individual masses:
18.02 g/mole H_2O

11. Moles to Mass Application:

How many grams of water in 8.50 moles?

$$8.50\,\cancel{moles\,H_2O} \bullet \frac{18.02\,g\,H_2O}{1\,\cancel{mole\,H_2O}} = 153\,g\,H_2O$$

12. Lithium Sulfate Example

Find the molar mass of lithium sulfate.

Formula = Li_2SO_4

Molar inventory:

Li: $2\,mol\,Li \bullet \frac{6.94\,g\,Li}{1\,mol\,Li} = 13.88\,g\,Li$

S: $1\,mol\,S \bullet \frac{32.07\,g\,S}{mol\,S} = 32.07\,g\,S$

O: $4\,mol\,O \bullet \frac{16.00\,g\,O}{mol\,O} = 64.00\,g\,O$

Sum of individual masses:
109.95 g/mole Li_2SO_4

Homework

Read 3.5 - 3.7

3.1 - 3.4 Problems in your Booklet
Due: Next Class.

Error: #13 should be Ag-109 (not 151)