BERKELEY MATH CIRCLE

The Math of Chemistry: Avogadro's Number, Moles & Molecules

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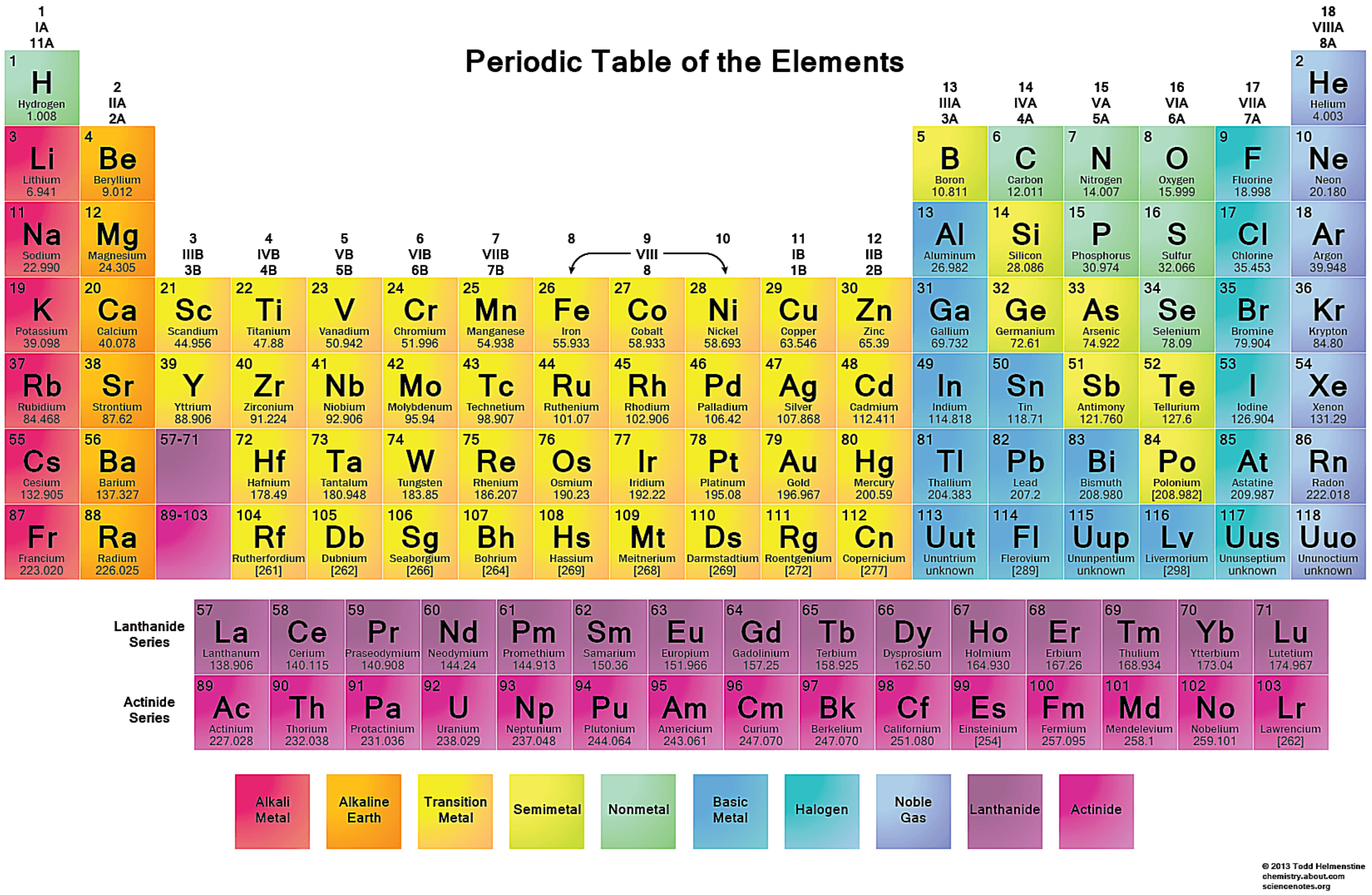
The Periodic Table

Elements are organized into the Periodic Table of Elements. They are organized into columns by their similarities in chemical properties:



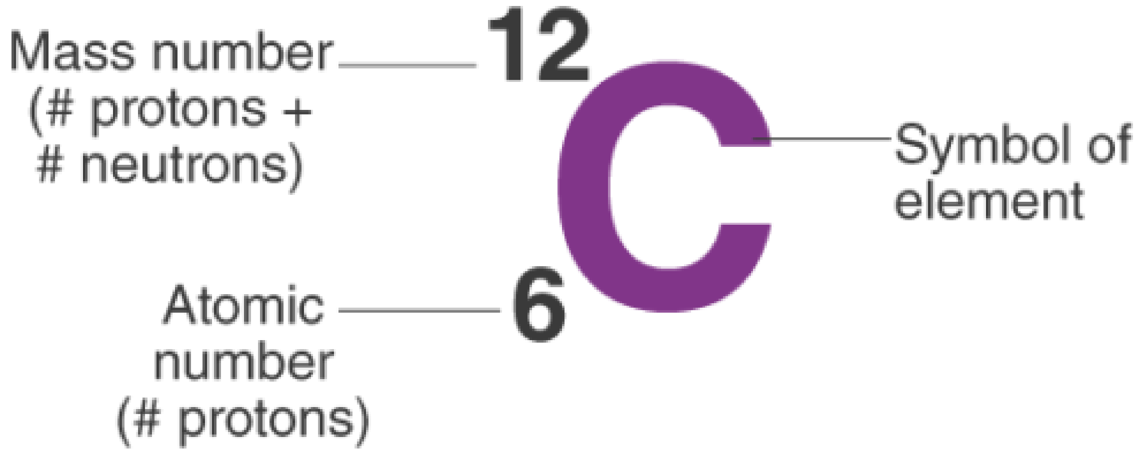
FROM LAST SEMESTER:

For each element, we can directly relate the amount of protons, electrons and neutrons that exist.
But first, we need to learn some terms!

Symbol of Element
1 or 2 letter abbreviation for each element

Mass Number
- *Not always a whole number (more on this later!)*
- *#protons + #neutrons*

Atomic Number
#protons (defines the element!)



Thus,

# of protons = atomic number (defines the element!)
# of electrons = # of protons (if neutral)
# of neutrons = Mass Number - Atomic number

When we think of atoms, we can’t “see” them, but we can measure them. We call this a **microscopic** view. But what about a **macroscopic** view? What things can we see, and then also measure? How do we measure them?

For example:

Pencil = graphite = carbon = C

table salt = sodium chloride = NaCl

balloons = helium = He

If we measure our examples, how do we compare them? By weight? By mass?

Since all of theses elements exist as whole atoms, the only way to compare/measure them on **equal standing** is by measure/counting **how many** of them exist. Their mass may be different, but the amount of them may be the same. In essence we, are counting how may particles of each element or molecule exist. Any guesses how many atoms in each of these? **A LOT!!!!**

Since we are dealing with very, very small objects, we need a way to count them in an easily digestible manner. Just like 1 dozen = 12, or 1 kilometer = 1000m, we need small, digestible values to represent INSANELY huge amounts.

We therefore welcome the concept of **Avogadro's Number** (NOT Avocado!)!

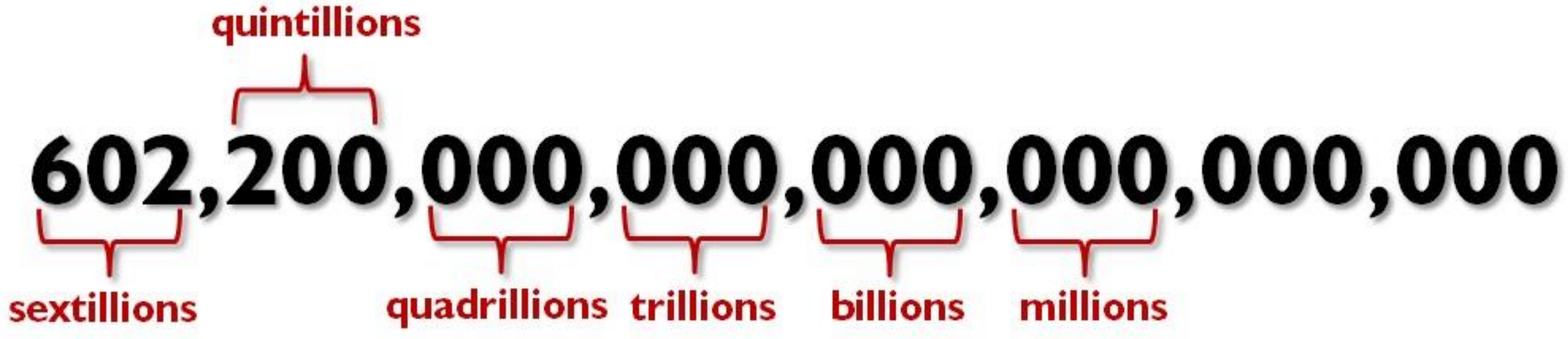
Avogadro $\neq$ **Avocado**

Avogadro's number is **6.022×10^{23} .** That's a HUGE amount!

How huge? Well . . . .

602,200,000,000,000,000,000,000

602.2 Sextillion!

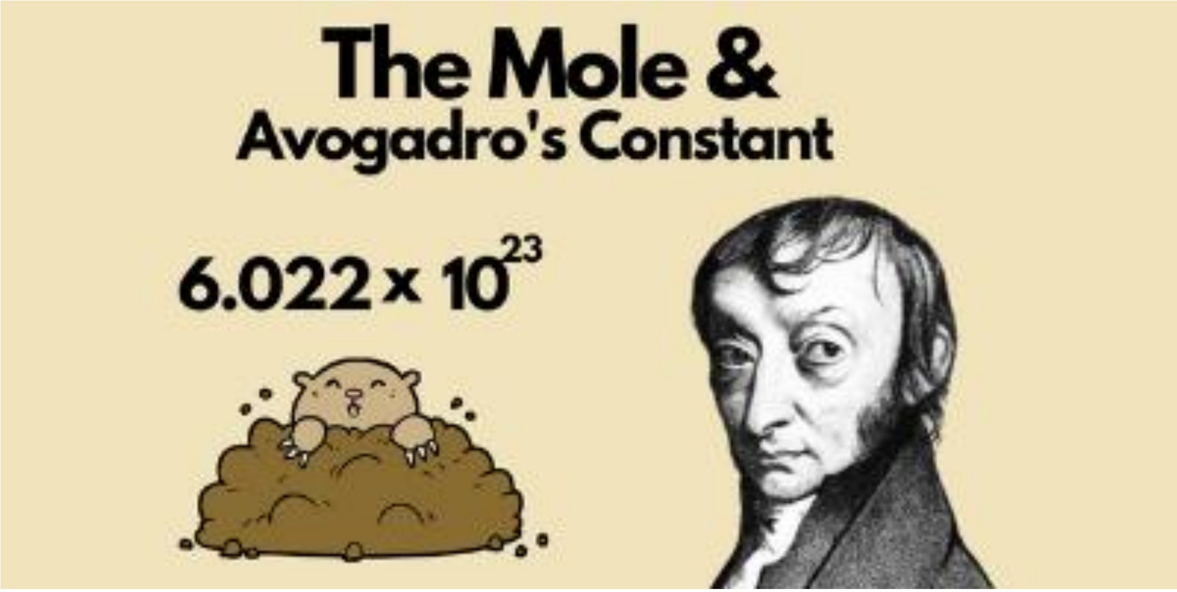


What then, does this HUGE number represent?

6.022×10^{23} = 1 **mole** of things (atoms, particles, molecules)

Again, just like:

1 dozen = 12
1 kilo = 1000
1 mole = 6.022×10^{23}



So, we've learned two new concepts:

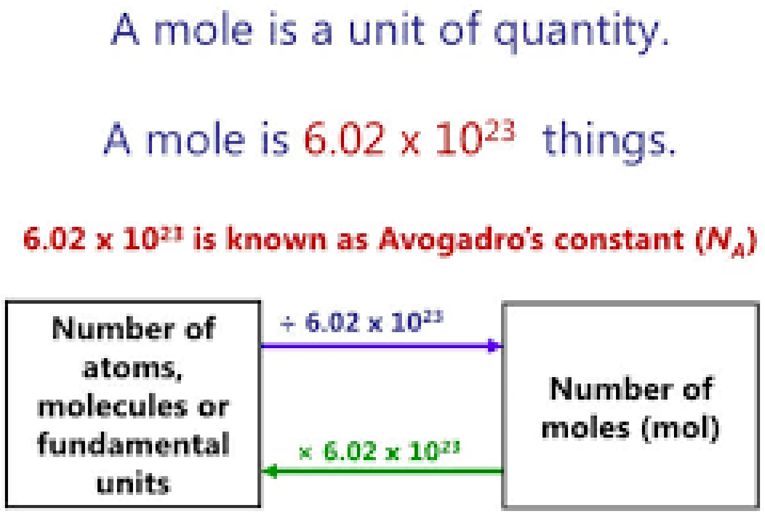
Avogadro's Number AND the **Mole**

How does all relate back to our microscopic and macroscopic view of things? From before:
*Since all of theses elements exist as whole atoms, the only way to compare/measure them on **equal standing** is by measure/counting **how many** of them exist.*

So:

1 mole of atoms = Avogadro's number of atoms

1 mole of atoms = 6.022 x 10^{23} atoms



Again, from before:
Their mass may be different, but the amount of them may be the same. In essence we, are counting how may particles of each element or molecule exist.

We will relate all of this to mass soon, but first, let's play with scientific notation, powers of ten, and numbers of things!

Math Fun!

To simplify, let's use 6.02×10^{23} = 1 mole of things for Avogadro's Number. You DO NOT need a calculator ;)

1) I have 2 moles of carbon. How many atoms of carbon do I have?

$$\frac{2 \text{ moles Carbon}}{1} \times \frac{6.02 \times 10^{23} \text{ atoms of Carbon}}{1 \text{ mole of Carbon}} = 2 \times (6.02 \times 10^{23}) = 12.04 \times 10^{23} = \mathbf{1.204 \times 10^{24}} \textbf{ atoms of carbon}$$

2) I have 0.5 moles of salt (NaCl). How many molecules of salt do I have?

$$\frac{0.5 \text{ moles NaCl}}{1} \times \frac{6.02 \times 10^{23} \text{ molecules of NaCl}}{1 \text{ mole of NaCl}} = 1/2 \times (6.02 \times 10^{23}) = \mathbf{3.01 \times 10^{23}} \textbf{ molecules of NaCl}$$

3) I have 5 moles of water (H_2O). How many molecules of water do I have?

$$\frac{5 \text{ moles } H_2O}{1} \times \frac{6.02 \times 10^{23} \text{ molecules of } H_2O}{1 \text{ mole of } H_2O} = 5 \times (6.02 \times 10^{23}) = 30.1 \times 10^{23} = \mathbf{3.01 \times 10^{24}} \textbf{ molecules of } \mathbf{H_2O}$$

More Math Fun!

To simplify, let's use 6.02×10^{23} = 1 mole of things for Avogadro's Number. You DO NOT need a calculator ;)

1) I have 2.408×10^{28} atoms of Calcium (Ca). How many moles of Calcium do I have?

$$\frac{2.408 \times 10^{28} \text{ atoms of Calcium}}{1} \times \frac{1 \text{ mole of Calcium}}{6.02 \times 10^{23} \text{ atoms of Calcium}} = \frac{2.408 \times 10^{28}}{6.02 \times 10^{23}} = \frac{24.08 \times 10^{27}}{6.02 \times 10^{23}} = \mathbf{4 \times 10^{4} \text{ moles Ca}}$$

2) I have 3.01×10^{20} molecules of carbon dioxide (CO_2). How many moles of CO_2 do I have?

$$\frac{3.01 \times 10^{20} \text{ molecules } CO_2}{1} \times \frac{1 \text{ mole of } CO_2}{6.02 \times 10^{23} \text{ atoms of } CO_2} = \frac{3.01 \times 10^{20}}{6.02 \times 10^{23}} = \frac{1 \times 10^{20}}{2 \times 10^{23}} = 0.5 \times 10^{-3} = \mathbf{5 \times 10^{-4} \text{ moles } CO_2}$$

I have 1.806×10^{25} particles of helium gas (He). How many moles of helium do I have?

$$\frac{1.806 \times 10^{25} \text{ particles He}}{1} \times \frac{1 \text{ mole of He}}{6.02 \times 10^{23} \text{ particles He}} = \frac{1.806 \times 10^{25}}{6.02 \times 10^{23}} = \frac{18.06 \times 10^{25}}{6.02 \times 10^{23}} = \mathbf{3 \times 10^{2} \text{ particles He}}$$

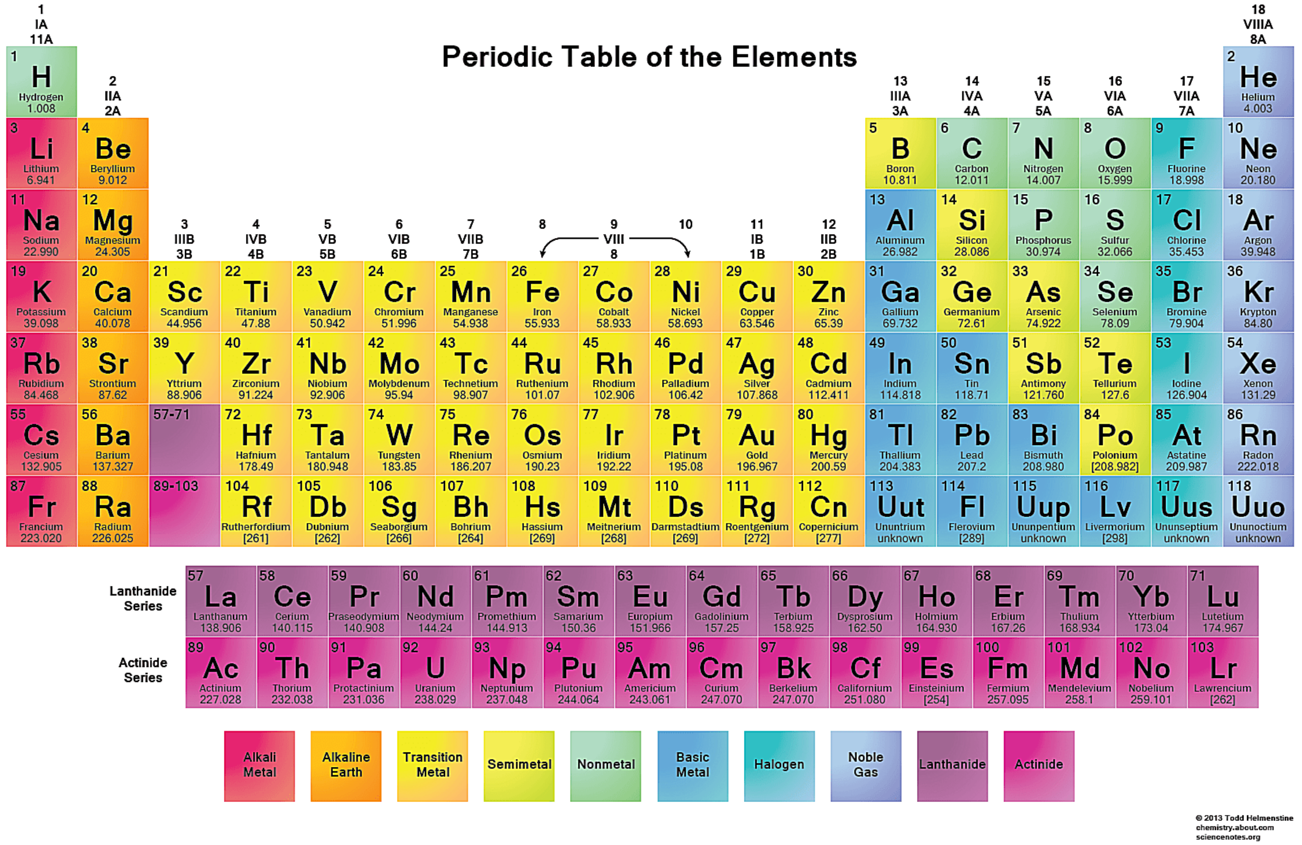
BUT, how does this relate to what we see and measure in day-to-day life! From before, we had the objects below. Can we say?

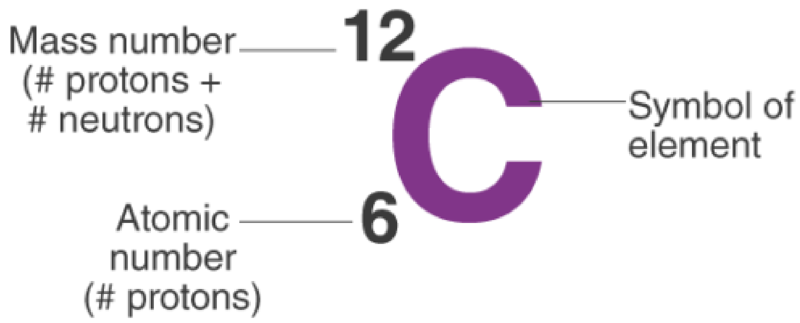
“I have 6.022×10^{23} atoms of carbon in my pencil”
“Please pass me 3.01×10^{23} particles of salt”
“May you fill my balloon with 1.04×10^{24} atoms of Helium?”

Of course not! **That’s ridiculous!**

We tend to measure things by their mass, and then relate them to how many of them exist (atoms, molecules, moles, etc.). So, we need to a way to do so . . . .

Our good friend, **The Periodic Table of Elements** is here to help us again! Without getting into all of the background, scientists have discovered that an Avogadro's amount of any element/atom = 1 mole of that element/atom, and is ALSO equal to that element/atom's atomic mass when measured in **grams.**





For Example:

6.022×10^{23} atoms of Lithium
1 mole of Lithium
6.941 grams of Lithium

6.022×10^{23} atoms of Aluminum
1 mole of Aluminum
26.982 grams of Aluminum

It's also ADDITIVE! Table Salt = Sodium Chloride

+

=

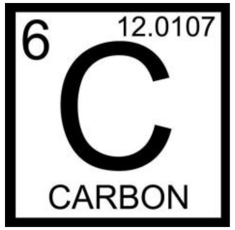
6.022×10^{23} molecules of NaCl
1 mole of NaCl
22.990 + 35.453 = 58.443 grams of NaCl

Even More Math Fun!

To simplify, let's use 6.02×10^{23} = 1 mole of things for Avogadro's Number. Also, round off mass numbers to their first decimal space. For example, Nitrogen's mass number is listed as 14.007, so use 14.0.

1) I have 2 moles of carbon. How many grams of carbon do I have?

$$\frac{\text{2 moles of Carbon}}{1} \times \frac{\text{12 grams Carbon}}{\text{1 mole of Carbon}} = \textbf{24 grams of Carbon}$$

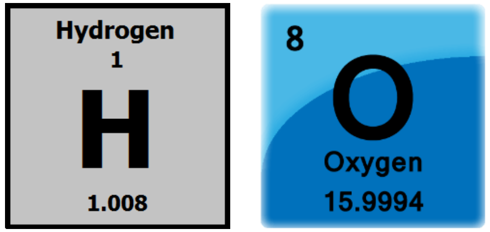


2) I have 0.5 moles of salt (NaCl). How many grams of salt do I have?

$$\frac{\text{0.5 moles of NaCl}}{1} \times \frac{\text{58.4 grams NaCl}}{\text{1 mole of NaCl}} = \textbf{29.2 grams of NaCl}$$

3) I have 5 moles of water (H_2O). How many grams of water do I have?

$$\frac{\text{5 moles of } H_2O}{1} \times \frac{\text{18 grams } H_2O}{\text{1 mole of } H_2O} = \textbf{90 grams of } \mathbf{H_2O}$$



More than Even More Math Fun!

To simplify, let's use 6.02×10^{23} = 1 mole of things for Avogadro's Number. Also, round off mass numbers to their first decimal space. For example, Nitrogen's mass number is listed as 14.007, so use 14.0.

1) I have 80.2 grams of Calcium (Ca). How many moles of Calcium do I have? How many atoms of Calcium do I have?

2) I have 132 grams carbon dioxide (CO_2). How many moles of CO_2 do I have? How many molecules of CO_2 do I have?

3) I have 30 grams of helium gas (He). How many moles of helium do I have? How many particles of He do I have?

The MOST Math Fun EVER!

To simplify, let's use 6.02×10^{23} = 1 mole of things for Avogadro's Number. Also, round off mass numbers to their first decimal space. For example, Nitrogen's mass number is listed as 14.007, so use 14.0.

1) Pick your favorite Element from the PT. Write down it's element abbreviation and mass number.
2) Square your age.
3) Your age squared is a how many grams of your favorite element you have.
4) Calculate how many moles of your element you have.
5) Calculate how many atoms of your element you have.