BERKELEY MATH CIRCLE

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

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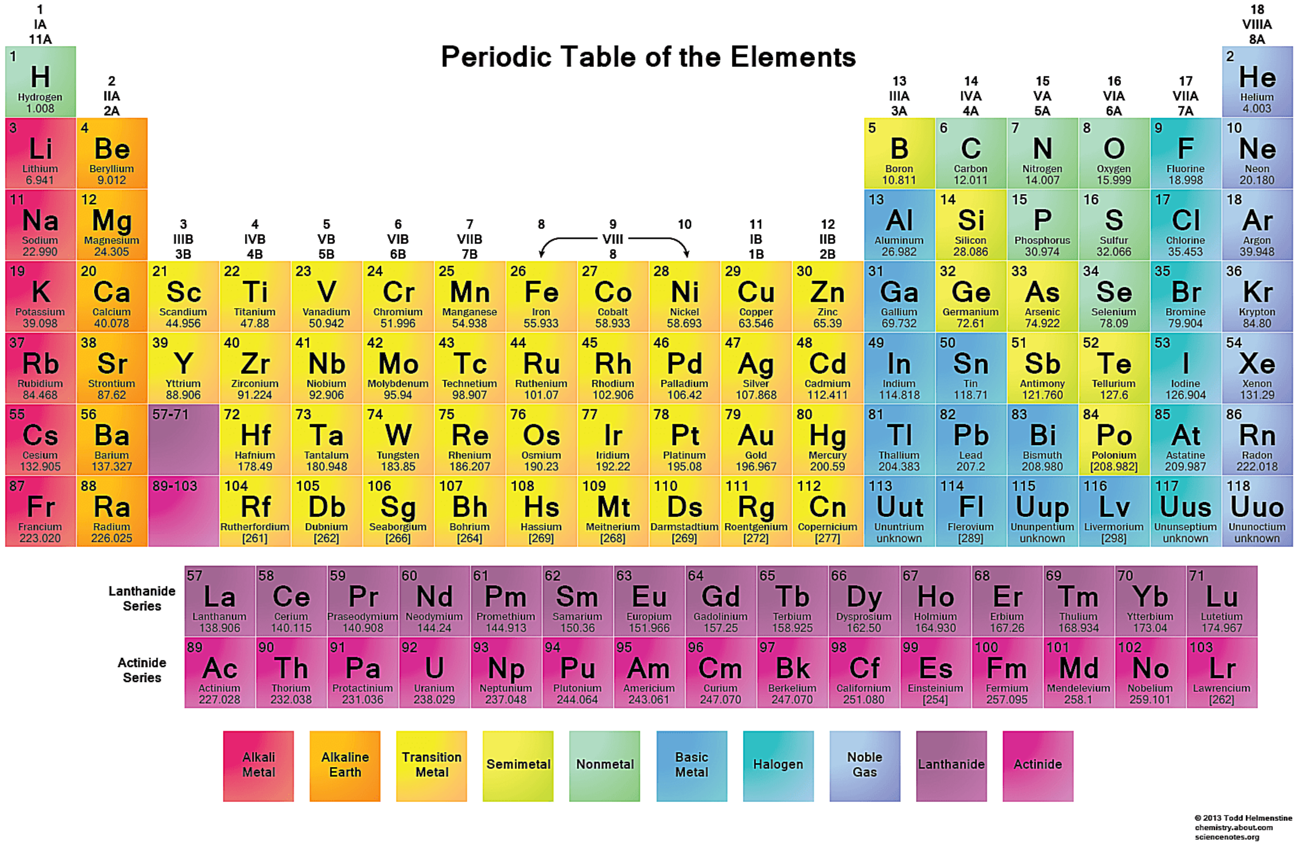
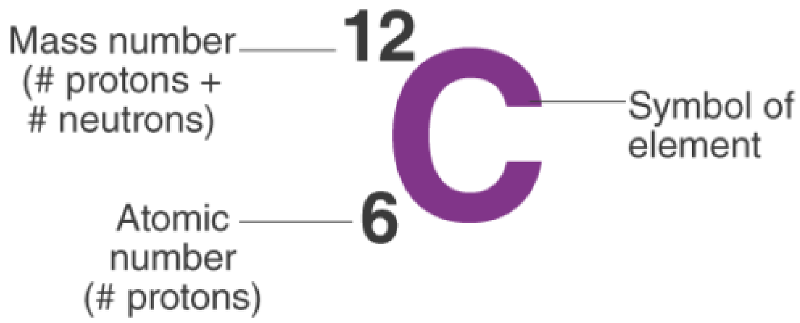
The Periodic Table





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?

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40.1

$$\frac{80.2\,g\,Ca}{1} \times \frac{1\ mole\ Ca}{40.1\,g\,Ca}$$

2 moles Ca

More than Even More Math Fun!

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$$\frac{2 \text{ moles Ca}}{1} \times \frac{6.02 \times 10^{23} \text{ atoms Ca}}{1 \text{ mole Ca}}$$

12.04×10^{23} atoms Ca

1.204×10^{24}

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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?

$$80.2\text{ g Ca} \times \frac{1\text{ mole Ca}}{40.1\text{ g Ca}} = 2\text{ moles Ca}$$

$$2\text{ moles Ca} \times \frac{6.02 \times 10^{23}\text{ atoms of Ca}}{1\text{ mole Ca}}$$

$$12.04 \times 10^{23} = 1.204 \times 10^{24}\text{ atoms Ca}$$

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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?
BONUS Question: How many atoms of Oxygen do I have?

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#1

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? *BONUS Question: How many atoms of Oxygen do I have?*

$$CO_2 = 12 + 2(16) = 44\,g/1\,mole$$

$$\frac{132\,g\,CO_2}{1} \times \frac{1\,mole\,CO_2}{44\,g\,CO_2} = 3\,moles\,CO_2$$

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.

#2

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?
BONUS Question: How many atoms of Oxygen do I have?

$$\frac{3 \text{ moles } CO_2}{1} \times \frac{6.02 \times 10^{23} \text{ molecules } CO_2}{1 \text{ mole } CO_2}$$

$$18.02 \times 10^{23} = 1.802 \times 10^{24} \text{ molecules } CO_2$$

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.

1C, 2O

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?
BONUS Question: How many atoms of Oxygen do I have?

$$1.806 \times 10^{24} \text{ molecules } CO_2 \times \frac{2 \text{ Oxy}}{1 \, CO_2}$$

$$3.612 \times 10^{24} \text{ atoms O}$$

What Have We Learned?

We relate quantities in Chemistry but how many PHYSICAL items exist. This is why knowing Avogadro's number and the concept of a mole is so important! If we are trying to calculate specifically what is happening, we MUST know how many things are interacting with how many other things, and we do so via moles. Therefore, the relationship below is KEY to understanding chemical interactions:

# of Particles←→ Moles ←→ Grams

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PT

# of Particles ←→ Moles ←→ Grams

Molar Mass

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# of Particles ←→ Moles ←→ Grams

Let’s Expand This!

Let’s use our NEW understanding to understand something we probably ALL have done: the famous at-home volcano experiment!

Does anyone know what is happening in that experiment?

Let's Expand This!

The basics are that we mix vinegar with baking soda and BOOM! But what's happening on a chemical level?

Vinegar contains Acetic Acid (CH_3COOH). This is found in liquid form.
Baking Soda contains sodium bicarbonate ($NaHCO_3$). This is found in solid form.

So,
$CH_3COOH + NaHCO_3 \rightarrow Na^+ + CH_3COO^- + H_2CO_3$ (carbonic acid, which decomposes (see below))

And then
$H_2CO_3 \rightarrow H_2O + CO_2$

Carbon Dioxide is a gas which then escapes into the air. This is what causes the "lava" movement in the experiment!

Relating back to Earlier . . .

$CH_3COOH + NaHCO_3 \rightarrow Na^+ + CH_3COO^- + H_2CO_3 \rightarrow H_2O + CO_2$

One can relate how much acetic acid and sodium carbonate will react (assuming a full reaction) by using our previous relationship and expanding on it . . . .

Previously we had . . .

# of Particles←→ Moles ←→ Grams

And we can use this for BOTH the acetic acid and sodium carbonate.

BUT, how do we relate them to each other?

The Mole Bridge!

# of Particles←→ Moles ←→ Grams

# of Particles←→ Moles ←→ Grams

The Mole Bridge!

# of Particles ←→ Moles ←→ Grams

↕

# of Particles ←→ Moles ←→ Grams

The Mole Bridge!

The mole bridge is part of a concept in Chemistry called Stoichiometry.

Stoichiometry = the relationship between the relative quantities of substances taking part in a reaction

Back to volcanoes then . . . .

Volcano Problem

$CH_3COOH + NaHCO_3 \rightarrow Na^+ + CH_3COO^- + H_2CO_3 \rightarrow H_2O + CO_2$

If I used 100 grams of Acetic Acid, how many grams of Sodium Bicarbonate will I need to measure out in order to react all of the 100 grams of Acetic Acid?

Volcano Problem

CH_3COOH → 60g/1 mole (from PT table)

$NaHCO_3$ → 84g/1 mole (from PT table)

1:1 ratio of CH_3COOH to $NaHCO_3$ from chemical equation

100 grams CH_3COOH x 1 mole/60 g = 5/3 moles CH_3COOH ← 1:1 ratio → 5/3 moles $NaHCO_3$ x 84 g/mole = 140 g

of Particles←→ Moles ←→ Grams

of Particles←→ Moles ←→ Grams

The Mole Bridge!

Acetic Acid

# of Particles ←→ 1 Moles ←→ Grams

60g/mole

100g

NaHCO3

# of Particles ←→ 1 Moles ←→ Grams

140g

84g/mole

$$100\,g\,AA \times \frac{1\,mole}{60\,g} \times \frac{1\,NaHCO_3}{1\,AA} \times \frac{84\,g}{1\,mole}$$

$$\boxed{140\,g\,NaHCO_3}$$