Avogadro's number is 6.02×10^{23}, which equals 1 mole of anything.

Why the weird number? In the following balanced chemical equation, the coefficients in front of the reactants and products indicate the ratio of materials that are needed or that will be produced. They basically mean, "Two measures of hydrogen gas will react with one measure of oxygen gas to produce two measures of water."

$$2\, H_2 + O_2 \rightarrow 2\, H_2O$$

To predict the outcome of chemical reactions, we need a dependable way to measure out accurate numbers of molecules, atoms, or ions of any material. Avogadro's number is a scaling factor between macroscopic and microscopic observations of nature. Its current value is the number of atoms in exactly 12 grams of carbon-12. Using molar conversion skills, scientists can predict not only the product of a chemical reaction, but also how much of the product will be made.

Simplest explanation: Some numbers are so important to the way we do things that they have special names, like "pi" or "pair" or "dozen." One dozen is 12 of anything, right? So 2 dozen would be 24 of anything.

BASIC MOLAR CONVERSION SKILLS:

Finding the Atomic Mass (AM) or Molar Mass (MM) Materials

Example 1 – AM of an Element: The atomic mass of any element is the mass number listed for that element on the periodic table.

What is the mass of 1 mole of calcium atoms?
Directly from the periodic table, 1 mol Ca = 40.078 g Ca

Example 2 – MM of a Compound: The molar masses of compounds are needed to do molar conversion problems in chemistry. Remember that the subscripts in a chemical formula indicate how many atoms of each element there are in the molecule. These also can mean the number of moles of each material in one mole of the compound. To find the MM of a compound, add up the atomic masses of all the elements that make up the compound.

What is the molar mass of H_2SO_4?

<u>1 mol of H2SO4 contains the following:</u>

$$\begin{array}{lrl} & 2\text{ mol H }(1.008\text{ g}) & = 2.016\text{ g} \\ & 1\text{ mol S }(32.065\text{ g}) & = 32.065\text{ g} \\ + & 4\text{ mol O }(15.999\text{ g}) & = 63.996\text{ g} \\ \hline & \text{MM of } H_2SO_4 & = 98.08\text{ g/mol} \end{array}$$

(4 sig figs)

Moles ↔ Particles

Example 1 (moles to atoms): If you are given a small dish of pure carbon powder (ground charcoal) and were told there are 3.2 moles of carbon on the dish, how many atoms of carbon would that be?

$$\frac{3.2\ \cancel{mol\ C}}{1} \cdot \frac{6.02x10^{23}\ atoms\ C}{1\ \cancel{mol\ C}} = 1.9x10^{24} atoms\ C$$ (2 sig figs)

Example 2 (moles to molecules): If you are told there are 4.32 moles of water in a container, how many molecules of water are there?

$$\frac{4.32\ \cancel{mol\ H_2O}}{1} \cdot \frac{6.02x10^{23}\ molecules\ H_2O}{1\ \cancel{mol\ H_2O}} = 2.60x10^{24}\ molecules\ H_2O$$ (3 sig figs)

Moles ↔ Mass

Example 1 (grams to moles): If you were given a small pile of yellow sulfur powder, you could figure out the number of moles of atoms in the pile if you find its mass, but remember to subtract out the mass of the dish. How many moles are in 423.7 grams of sulfur?

You need to look up the atomic mass (AM) of sulfur

$$\frac{423.7\ \cancel{g\ S}}{1} \cdot \frac{1\ mol\ S}{32.065\ \cancel{g\ S}} = 13.21\ mol\ S$$ (4 sig figs)

Example 2 (moles to grams): If you were told that a beaker contains 12.64 moles of magnesium nitrate, what is the mass of the material?

First… The chemical formula for magnesium nitrate is $Mg(NO_3)_2$

Second… find the compound's molecular mass (MM)

2 mol H (1.008 g) = 2.016 g
1 mol S (32.065 g) = 32.065 g
\+ 4 mol O (15.999 g) = 63.996 g

MM of H_2SO_4 = 98.08 g/mol (4 sig figs)

Third… use the molar mass as a conversion factor

$$\frac{12.64\ \cancel{mol\ Mg(NO_3)_2}}{1} \cdot \frac{98.074\ g\ Mg(NO_3)_2}{1\ \cancel{mol\ Mg(NO_3)_2}} = 1240\ g\ Mg(NO_3)_2$$ (4 sig figs)

Moles ↔ Moles

If you have balanced chemical equation in preparation for an experiment, you can use the ratios of coefficients of the reactants and products to make predictions about the outcome of the experiment.

Example: For the following balanced chemical equation (the combustion of the propane), how many moles of carbon dioxide would you expect to be produced if you completely burn 17.3 moles of propane (C_3H_8)?

$$C_3H_8 + \mathbf{5}\ O_2 \rightarrow \mathbf{3}\ CO_2 + \mathbf{4}\ H_2O$$

Realize that the balanced equation for this reaction means that complete combustion of 1 mole of C_3H_4 will produce 3 moles of CO_2. So, the conversion factor relating propane to carbon dioxide is $1\ mol\ C_3H_8 : 3\ mol\ CO_2$

$$\frac{17.3\ \cancel{mol\ C_3H_8}}{1} \cdot \frac{3\ mol\ CO_2}{\cancel{1\ mol\ C_3H_8}} = 51.9\ mol\ CO_2$$

Moles ↔ Volume of Gas

Avogadro's real discovery was that 1 mole of any gas at will always occupy 22.4 L of volume at standard temperature and air pressure (STP). Chemists call this rule **Avogadro's Principle**. Also, STP is defined as 0° Celsius (273 Kelvin) and 1 atm (atmosphere) of atmospheric air pressure. This creates a useful conversion factor for measuring the number of moles of gas in a laboratory setting. $1\ mol\ of\ any\ gas\ at\ STP : 22.4\ L$

Importantly, Avogadro's Number is different from Avogadro's Principle. To honor Avogadro, the number mole was named after him. Avogadro's number is 6.02×10^{23}

Example: For the chemical reaction in the Moles ↔ Moles section of this document (combustion of propane), 51.9 mol of CO_2 was produced. How many moles of this gas is this?

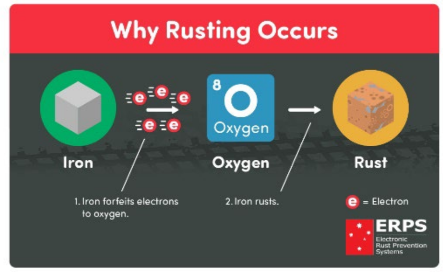
$$\frac{51.9\ \cancel{mol\ CO_2}}{1} \cdot \frac{22.4\ L}{1\ \cancel{mol\ CO_2}} = 1162.56\ Liters\ CO_2$$

The answer is best expressed in scientific notation due to sig figs: 1.16×10^3 L CO_2

USING MOLAR CALCULATIONS WITH BALANCED CHEMICAL EQUATIONS (Stoichiometry)

Step 1. List given (known) information
Step 2. List goal (unknown)
Step 4. Plan calculations and which conversion factors are needed
Step 3. Write balanced chemical equation for the reaction, look up or calculate conversion factors
Step 5. Start with known and work towards unknown, canceling units appropriately
Step 6. Answer should include (1) measurement, (2) unit, (3) material being measured, and (4) the right number of significant figures (adjust accuracy to match the information given in the problem).

See the example stoichiometry problem on the following page…



Stoichiometry Example (grams → moles → moles → grams):
During a laboratory experiment, 223.38 grams of solid iron metal will be allowed to react with atmospheric oxygen to produce solid iron (III) oxide (iron rust). Predict the number of grams of rust produced.

Step 1. List given (known) information

223.38 grams Fe will react with O_2 to make Fe_2O_3 (we had to use knowledge of molecular bonds to write the correct chemical formulas)

Step 2. List goal (unknown)

X grams of Fe_2O_3

Step 3. Plan calculations and determine which conversion factors are needed

We need to know the number of moles of Fe (grams → moles)

We need to convert moles of Fe to moles of Fe_2O_3 (moles → moles), so we need a balanced chemical equation for this reaction.

We need to convert the calculated moles of Fe_2O_3 to grams of Fe_2O_3 (moles → grams)

Plan (Logic Train): mass Fe → mol Fe → mol Fe_2O_3 → mass Fe_2O_3

Step 4. Look up or calculate the information needed for conversion factors.

Write balanced chemical equation for the reaction.
The skeletal equation is $Fe + O_2 \rightarrow Fe_2O_3$
The balanced equation is $\mathbf{4}\ Fe\ (s) + \mathbf{3}\ O_2\ (g) \rightarrow \mathbf{2}\ Fe_2O_3\ (s)$

Atomic Mass of Fe (Use periodic table):
$$1\ mole\ Fe = 55.845\ g$$

Molar Mass of Fe_2O_3 (Use periodic table):
$$2\ mole\ Fe\ (55.845\ g) = 111.69\ g$$
$$+\ 3\ mole\ O\ (15.999\ g) = 47.997\ g$$

$$MM\ of\ Fe_2O_3 = 159.687\ g/mol$$

Step 5. Start with known and work towards unknown, canceling units appropriately

$$\frac{223.38\ g\ Fe}{1} \cdot \frac{1\ mol\ Fe}{55.845\ g\ Fe} \cdot \frac{2\ mol\ Fe_2O_3}{4\ mol\ Fe} \cdot \frac{159.687\ g\ Fe_2O_3}{1\ mol\ Fe_2O_3} =$$

Cancelation of Units:

$$\frac{223.38\ \cancel{g\ Fe}}{1} \cdot \frac{1\ \cancel{mol\ Fe}}{55.845\ \cancel{g\ Fe}} \cdot \frac{2\ \cancel{mol\ Fe_2O_3}}{4\ \cancel{mol\ Fe}} \cdot \frac{159.687\ g\ Fe_2O_3}{1\ \cancel{mol\ Fe_2O_3}} =$$

Step 6. Write answer as (1) measurement, (2) unit, (3) material being measured, and (4) the right number of significant digits

Answer = 319.37 $g\ Fe_2O_3$ (5 sig figs)