VANCOUVER COMMUNITY COLLEGE

Why Use Moles?

Consider these two recipes:

82 kg of tires + 1042 kg of body + 639 kg of engine = 1 car
62.8 g of bread + 28.7 g of ham + 34.1 g of cheese = 1 sandwich

No one would make a car or sandwich using these measurements. They're not practical. A car has 1 body, 1 engine and 4 tires. A sandwich usually has 2 slices of bread, and 1 or more slices of ham and cheese. We don't weigh the pieces, we count them.

Chemical reactions work in a similar way. At the molecular level, atoms recombine into new molecules, and the molecules require a certain number of each kind of atom to be complete. This is why we use coefficients to describe reactions rather than masses — the masses aren't important. The quantity of atoms and molecules is. However, it's a lot harder to pick out exactly four molecules than it is to pick out four tires. Because molecules are so small, we measure solid chemicals by mass. We need some way to convert mass to quantities, and to be able to count molecules that are too small to see.

The solution to this problem is the concept of the **mole** (abbreviated "mol"). A mole is a fixed quantity of particles (6.022×10^{23} molecules, atoms, ions, …), in the same way that a dozen always means 12 of something (pencils, eggs, donuts, etc.). We can figure out how much a mole of any chemical should weigh because chemists have carefully determined how much a mole of any type of atom should weigh. From that information, we can calculate the mass of a mole of any molecule.

Think of it this way: If a catering company has an order for 500 ham and cheese sandwiches, the caterers need to know how many slices of bread are needed. Each sandwich takes 2 slices of bread, so 500 sandwiches will take 500 × 2 = 1000 slices. The caterers can order all their ingredients based on calculations like these to fill the order. We can do the same thing with molecules.

Example 1: Determine the mass of 1 mol of ethanol, C_2H_5OH.

Solution: Each molecule of C_2H_5OH consists of 2 carbon atoms, 6 hydrogen atoms and 1 oxygen atom. This means 1 mole of C_2H_5OH would have 2 mol of C atoms, 6 mol of H atoms and 1 mol of O atoms, bonded to form molecules. We can use information from the periodic table to get the mass of each "ingredient". These are called **molar masses**. The table says that 1 mol C is 12.01 g, 1 mol H is 1.01 g and 1 mol O is 16.00 g. The molar mass of C_2H_5OH is $2 \times 12.01 + 6 \times 1.01 + 1 \times 16.00 = 46.08\ \mathrm{g/mol}$. Since we want the mass of 1 mol, $46.08\ \mathrm{g/mol} \times 1\ \mathrm{mol} = 46.08\ \mathrm{g}$. The periodic table lists molar masses to many decimal places but for your course two decimal places is enough.

Now consider the combustion of ethanol. The reaction is:

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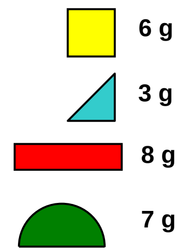
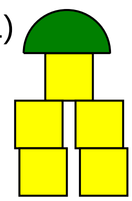
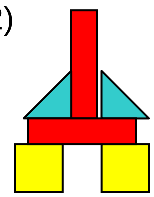
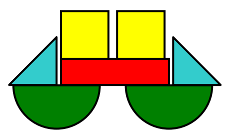
$$\underset{\text{ethanol}}{C_2H_5OH} + \underset{\text{oxygen}}{3\,O_2} \rightarrow \underset{\text{carbon dioxide}}{2\,CO_2} + \underset{\text{water}}{3\,H_2O}$$

How much oxygen does it take to combust 1 mol of ethanol? We can't determine the mass of the oxygen needed directly from the mass of the ethanol! We have to recalculate from molar masses, since the reaction happens based on molecules, not masses. The stoichiometry of the reaction says that 1 molecule of ethanol will react with 3 molecules of oxygen gas, which also means 1 mol C_2H_5OH will react with 3 mol O_2. Since 1 mole of oxygen atoms is 16.00 g, 2 mol O atoms is 32.00 g, and O_2 has a molar mass of 32.00 g/mol. 3 mol O_2 will be 32.00 g/mol × 3 mol = 96.00 g.

EXERCISES

A. The structures in the pictures below are like molecules: they're made from parts with known masses. The masses of different building blocks are shown at the right. Determine the masses of the structures below:



1)  2)  3) 

B. Consider the ethanol combustion reaction from the example.
   1) Determine the mass of 1 mol of carbon dioxide.
   2) Determine the mass of 1 mol of water.
   3) The total mass of the reactants when 1 mol of ethanol combusts is 142.08 g. What should the mass of the products be? Using the stoichiometry of the reaction, verify your answer.

C. Determine the mass of the following amounts of substances:
   1) 3.00 mol of water
   2) 4.00 mol of NH_4
   3) 2.50 mol of H_2SO_4
   4) 7.10 mol of LiH_2PO_4
   5) 5.50 mol of dinitrogen pentoxide
   6) 12.1 mol of potassium sulphide
   7) 1.36 mol of magnesium iodide
   8) 2.21 mol of phosphoric acid

D. Determine the number of moles of each chemical mass by calculating the chemical's molar mass and converting.
   1) 5.00 g of ethanol
   2) 12.0 g of NO_2
   3) 8.94 g of $CaCO_3$
   4) 136 g of silver chloride
   5) 74.5 g of lead (II) sulphate
   6) 38.8 g of strontium nitrate

SOLUTIONS

A. (1) 37 g (2) 34 g (3) 40 g

B. (1) 44.01 g/mol (2) 18.02 g/mol (3) The mass of the products must equal the mass of reactants, 142.08 g. [2 mol (44.01 g/mol CO_2) + 3 mol (18.02 g/mol H_2O) = 142.08 g]

C. (1) 54.1 g (2) 72.2 g (3) 245 g (4) 738 g (5) 594 g (6) 1330 g (7) 378 g (8) 217 g

D. (1) 0.109 mol (2) 0.261 mol (3) 0.0893 mol (4) 0.949 mol (5) 0.246 mol (6) 0.183 mol