

# **Amount of Substance and Its Unit – Mole- Connecting the Invisible Micro World to the Observable Macro World Part 1 (English, mp4)**

INSTRUCTOR: Hello everyone. Welcome to my Blossoms lesson. My name is Ling Wang[? Elaine Wong, ?] and I'm the liaison for the MIT Blossoms China partnership. Today, I'm here in a large chemistry lab at MIT. In this lesson, I'm going to talk about the two concepts, amount of substance and mole.

They may sound the less familiar to us and the mainly used by chemists. But they are fundamental core concepts in chemistry. And this lesson will help you to really understand them. Before talking about this, I have just come back from doing some shopping.

Now let's see what I've bought. I got one cantaloupe, one grape fruit, two apples, one box of blueberries and one box of strawberries. Here I have got a question for you. Have you noticed that some fruits can be so by the piece. For example, I can buy one cantaloupe, one grapefruit, even one apple. But can I just buy one strawberry or one blueberry?

No, you can't, because they are usually sold in packs. Why? Look, they are very small in size. It's harder to handle if they are sold or bought by the piece. We have to pack them together and sell them in boxes or bags. You may ask what is the connection between the fruits and a mole. You will understand it later.

Right now, I have something I want you and your classmates to do. First of all, I want you to discuss with your fellow students what you know about the term amount of substance. After that, your teacher will have a bag of beans. And I want you to come back after the break with the precise weight of one single bean. See you in a few minutes.

Hi everyone, did you have a good discussion about the term amount of substance? What does it mean? As its name suggests, this term may refer to the quantity of something. But what does it measure? Actually, amount of substance refers to a quantity fundamental to chemistry, that is used to measure how many elementary entities are present in a substance. These elementary entities might to be atoms, molecules, ions, electrons, or other specified group of tiny particles.

Amount of substance, symbol  $n$ , is one of the seven base quantities defined by the SI, the international system of units. Now that you know what the concept amount of substance means, let's move on to the next the concept, mole. This mole is not the animal living underground.

In chemistry, moles, symbol mol, is the unit of amount of substance. Just as meter is the unit of length, kilogram is the unit of mass, second is the unit of time, and thus among seven base [? 7 base ?] SI units too. For example, if I ask how long is this table, or what is the length of this table, you should answer it is 2 meters. Here, meter is the unit of length.

If I ask how much does this cantaloupe weight or what is the weight of this cantaloupe, you might answer it's two pounds. Here, pound is the unit of mass. Or similarly, if I ask what is the amount of substance in 18 grams of water, you should answer the amount of substance in 18 grams of water is one mole, But how can we know the answer is one mole. After this lesson, you will easily answer this type of questions.

This mole can be a very difficult concept to understand. Which is why I ask you about the precise weight of a bean. Did you find the weight of a single bean? If so, how did you measure it? Well, let me try to find that weight.

When I put one bean on the scale, the scale shows nothing because the weight of the one being is too small to be measured with this kitchen scale. But how about we put 100 beans together and get the weight of the pile of these beans by using this scale.

Then we can divide this weight by 100. And we know the weight of one single bean. With these beans, the weight of one single bean is about 200 milligrams. So if something is small in size, we can group them together and give the group a unit term where we are handling it. That's why rice, beans, candies, blueberries, are sold in packs.

For example, eggs also sold in packs. Usually we use dozen to describe the number of eggs. The unit dozen is defined as a group of 12, which means we put 12 eggs in a group and use dozen as the unit term of this group. So one dozen eggs is equal to 12 eggs. Two dozen is equal to 24 eggs. Sometimes it is more convenient if people use that dozen to describe the amount of eggs, especially when ordering large amount of eggs.

For instance, 180 eggs, for this amount of eggs, people can directly say 15 dozen eggs instead of the number of 180 and make fewer mistakes during the operation. Before looking further at small elementary particles we cannot see, let's do one more example relating to the concept of amount of substance.

Different regions of the world have reasons to create some new units to describe the amount of certain substances unique to their own needs. For instance, your region of the world may not have heard of a dozen eggs before. Here in North America, in the United States and Canada, many people burnt wood to heat their homes. So we need an amount of substance for wood.

It's called a cord of wood and is defined as shown on the screen right now. The cord is a unit of measure of dry volume used to measure firewood and the pulp wood in the United States and Canada. A cord is the amount of wood that when racked and well stowed occupies a volume of 128 cubic feet.

Now I have an assignment for you. With your classmates and with your teacher, discuss your regions unique needs and identify the unit of amount of certain substance that is needed in your part of the world. See you back in a few minutes.

Hi, did you have a good discussion with your fellow students? I'm sure you have found some interesting counting units used just in your region. For example, one ream of paper is equal to

500 sheets of paper. One gross is equal to 12 dozens. One score is equal to 20. As you can see, these counting units are all created by humans. And the people define the quantity of each unit according to their own needs.

For example, when measuring the quantity of paper, we designed the unit ream, and defined one ream is equal to 500 sheets of paper, because one sheet of paper is thin. And we needed to stack hundreds of paper to make it convenient for us to operate. However, when we are counting eggs, we designed a unit dozen.

And according to how many we can eat, we gave a dozen a smaller number, 12, compared to a ream. You see, these units of amount of different substances is human defined quantities. Quite arbitrary, but very useful. Now let's talk more about extremely small elementary entities.

And first, I want you to think about just how small an elementary entity really is. Remember, that elementary entity refers to the tiny particles like molecules, atoms, ions, electrons, and others, which compose all substance. So think about these tiny particles. And I want you and your classmates to answer the following question.

If 20 drops of water measures about 1 milliliter of water, and one water molecule weighs  $2.99 \times 10^{-23}$  grams, then how many molecules are there in one drop of water? After you get the answer, I want you to spend some time with your group discussing this.

If we want to put these tiny molecules of water into one group and design a new unit for this group, like dozen, to describe the number of these tiny molecules of water, how many molecules do you think we should put in a group?

Hi, have you got your answers? Are you surprised by the number of molecules in just one drop of water? It is pretty amazing. Here's the number of water molecules in one drop of water. Look at all these zeroes, how big this number is. On the other hand, given that one tiny drop of water has so many molecules, you can imagine just how small one water molecule is.

For such tiny particles what unit did scientists choose to count them? And if you are the scientists, how many molecules do you think should be in a group? Let's see what scientists selected. Owing to their tiny size, atoms and molecules cannot be counted by direct observation. So instead, scientists group these tiny particles together so that we can identify them when they are grouped together, and then deal with them in groups.

Just as we counted the beans, the new chosen unit for measuring the number of molecules or atoms is mole. In the first activity, we put 100 beans into one group. However, because the size of molecules is much, much smaller than a bean, so the number of atoms in one mole, should be much, much greater than 100.

As we know from the last activity, one drop of water has  $1.67 \times 10^{21}$  water molecules. But even though one drop of water that measures about 0.05 milliliter is visible to us, it's still too small to measure it conveniently and accurately with normal cylinders. Let's think of

something that we use in our daily lives that we could use to estimate a counting unit for extremely small particles.

What do you usually use to measure water or other liquid in your daily lives? Think about it and then according to you it's measuring range, make an estimate of how many water molecules scientists should put in a counting group.

Hi, welcome back. So what measuring device that we use in our daily lives did you use to estimate the number of molecules that scientists put in a mole? Well, I chose a teaspoon and a tablespoon because they're most used for measuring in cooking or baking. One teaspoon is about 5 milliliters. And one tablespoon is about 15 milliliters.

From the calculation, we find that one teaspoon of water has about  $1.67 \times 10^{23}$  molecules. And one tablespoon of water have about  $5.01 \times 10^{23}$  molecules. So we predict that if we think about putting water molecules in one group, the order of magnitude of number of molecules in that group should be around 23.

We will come back to this and see if I'm right with this order of magnitude. Just as one dozen eggs equals 12 eggs, what is the exact number of items in one mole? Let's see how scientists define a mole. This definition can be confusing. So listen carefully.

Mole is the unit of the amount of substance, symbol mol. One mole is defined as the amount of substance containing the same number of elementary entities as there are atoms in 12 grams of pure carbon-12. To make it easier to understand, in other words, if we know how many atoms are there in 12 gram carbon-12, then we know one mole of anything has the same number of elementary entities. The elementary entities in the mole definition refer to atoms, molecules, or ions, depending on the substance concerned.

For example, if the substance is water, because water is composed of water molecules, the elementary entities are water molecules. If it's carbon or copper, which are composed of atoms, the elementary entities are carbon or copper atoms. For iron compounds, such as sodium chloride, the entities are formula units of sodium chloride.

The number of carbon atoms in 12 grams of carbon-12 was determined experimentally by scientists. This number is called Avogadro's number. And it is really, really, really big. Usually we use Avogadro's number with three significant figures in calculation, which is  $6.02 \times 10^{23}$ . As you can see, the order of magnitude of Avogadro's number is 23.

See, my estimation is right. Was yours also close? Somewhere between 22 and 24, depending on what measurement device you choose for estimation. So far we have learned the definition of the amount of substance and a mole. The amount of substance is one of the seven basic physical quantities and used to measure the number of elementary entities at molecular or atomic level.

Mole's they unit of the amount of substance. One mole of anything has  $6.02 \times 10^{23}$  particles of basic units that compose the substance we referred. It can be difficult for anyone to imagine the magnitude of Avogadro's number. So after this class session, I want you to watch

another Blossom's lesson called "How Big is a Mole? Do we really Understand Avogadro's Number?"

Then, before you come to our next class session, I want you to find the answer to the following question. How long would it take for the people on earth to eat one mole of rice, assuming one person could eat 0.5 kilograms of rice per day. To answer this question, you might need to do some research online for the numbers you need to know. Good luck, and I will see you in the next class session.