Amount of Substance and Its Unit – Mole- Connecting the Invisible Micro World to the Observable Macro World Part 2 (English, mp4)

[MUSIC PLAYING]

Instructor: Hi, everyone. Welcome back. I hope you had some fun watching the BLOSSOMS lesson, How Big is a Mole? Did you find an answer to the question about eating rice? Can you believe it?

My estimate is that it would take about seven million years for the people on earth to eat one mole of rice. Was your estimate close to this range? Are you impressed with the incredible size of a mole, which is around 6.02 times 10 to the 23rd. This number also goes by the name of Avogadro's number.

And now I want to tell you how it got that name. Avogadro's number is named after the early 19th century Italian scientist Amedeo Avogadro, who, in 1811, first proposed that equal volumes of gases under the same conditions contain the same number of molecules. This hypothesis proved useful in determining the atomic and the molecular weights, and eventually led to the concept of a mole.

Many years later, the French physicist Jean Perrin proposed naming the constant in honor of Avogadro. But Dr. Avogadro himself, during his life, never saw this number that is now named after him. Avogadro's number, NA is equal to 6.02 times 10 to the 23rd, like any pure number is dimensionless, which means there is no unit attached to it.

However, it also defines the mole. So we can express NA as 6.02 times 10 to the 23rd per mole. In this form, it is properly known as Avogadro's constant. Now that we have learned about a new unit, a mole, let's do some exercise to deepen our understanding by answering the following question.

First, calculate the number of oxygen in 2 mole of oxygen. Second, calculate the amount of substance of the water that contains 3.612 times 10 to the 24th atoms. If you understand the mole concept, these are just simple multiplication or division calculations. But from this, I want you to generalize the relationship between the amount of substance and the number of particles. Think about it, and I will see you in a few minutes.

Welcome back. Have you got the answers to the last to activity? What are your answers to the first question? Actually, we couldn't get an answer, because we don't know the particular type of the elementary entity it asks about-- oxygen atoms or molecules. The answer is different for each.

So when using moles, we should always specify the elementary entities. Are they molecules, atoms, ions, or other specified group of such particles? Through the calculations we did in question number 2 of this last activity, we can easily summarize the relationship between the amount of substance, the number of particles, and Avogadro's constant. Because one more of any substance contains about 6.02 times 10 to 23rd elementary entities.

To find the number of particles N in a substance, we just multiply the amount of substance by Avogadro's constant. Reversely, to find the amount of substance in moles, we divide the number of particles, N, by Avogadro's constant. So Avogadro's constant, NA, is a conversion factor transferring the number of these invisible particles that we can't perceive on the molecular atomic level to the amount of substance that we can observe in the macro world by grouping 6.02 times 10 to the 23rd particles together.

As you can see, mole is like a magic bridge between the invisible world and the visible world we see around us. Think about it. One water molecule is invisible to our eyes. But one mole of water can be seen and measured.

If we use mole to replace the large number of molecules, which is 6.02 times 10 to the 23rd, it's much easier for us to figure out the scale of the amount. For example, it is far easier to figure out the difference between 100 moles of particles and one mole of particles, rather than trying to figure out the difference between 6.02 times 10 to the 25th particles and 6.02 times 10 to the 23rd particles. That would be really hard.

Here I have got another question for you. How could you measure out one mole of water molecules for me? To help you find the answer, let's think of the activity of weighing a single bean at the beginning of this lesson. Think about this question first. If we need 10,000 beans, assuming these beans have equal mass, how should we measure them?

Welcome back. I'm sure you have found a way to measure out 10,000 beans. Obviously, we don't want to count the beans one by one, because it takes too long. In our first activity, we grouped 100 beans as a unit and got the weight of this unit of 100 beans, which is about 20 grams. So by these two numbers, 100 beans and 20 grams, we can easily get the weight of 10,000 beans, which is 2,000 grams.

So we just need to measure 2,000 grams of beans to obtain the amount of 10,000 beans. In this case, the number 100 is just like Avogadro's number. The difference is the magnitude of these two numbers. For one mole, we put Avogadro's number of items together.

If we know the mass of one mole of a substance, just like the mass of the group of 100 beans, then we can find a way to translate between the amount of a substance in moles and mass. Why is this important? All of us studying chemistry know that a chemical equation reflects the quantitative relationship between the reactants and the products.

But the coefficients indicated before each chemical formula only show the proportion between the number of particles of the reactants and the products of a reaction. For example, this equation tells that two hydrogen molecules can react with one oxygen molecule to form two water molecules. Through the conversion factor, NA, then the equation also means that two moles of hydrogen can react with one mole of oxygen to form two moles of water. This ratio does not change.

How can we measure two moles of hydrogen, one mole of oxygen, or two moles of water, because we don't have any tools to do it? However, if we know the mass of one mole of hydrogen, oxygen, or water, we can convert the amount of substance in those moles into their masses or weights. These masses can be measured by any scale in macro world.

The mass of one mole of a substance is called its molar mass, symbol M. So NA is the first conversion factor transferring the number of invisible particles to the amount of substance. And M is the second conversion factor transferring the amount of substance to mass. With these two conversion factors, we can move from the microscopic relationship of the number of the particles to the macroscopic weight and volumetric relationships.

But just how can we find the molar mass of a substance? Here I have one mole of four substances-- iron, copper, zinc, aluminum. The four specimens are stamped with identifying letters, A, B, C, and D, and with one mole.

Though their sizes look different, the amount of substance of each of them is the same, one mole. For the next activity, I want you to find the mass of one mole of these specimens using a scale and write down your readings. Then compare them with the relative atomic masses of these specimens on the periodic table. By doing this, can you identify the elements in each of these specimens?

Welcome back. Were you able to identify these four specimens? From this activity, we can predict that the molar mass of a substance is numerically equal to its relative atomic mass. Let's look at another example, carbon. Actually, according to the definition of mole, we can easily get the molar mass of carbon-12, even without a scale.

Let's go over the definition of mole first. One mole is defined as the amount of substance of a system which contains as many elementary entities as there are atoms in 12 grams of carbon-12. According to this definition, the answer is obvious. 12 grams of carbon-12 contain one mole of carbon-12 atoms. So the mass of one mole of carbon-12 is equal to 12 grams. So the molar mass of carbon-12 is 12 grams per mole.

So is the molar mass of a substance always numerically equal to its relative atomic mass? To find their relationship, let's go over that definition of relative atomic mass. Because the actual mass of an atom is very small, for convenience, scientists defined 1/12th of the mass of a carbon-12 atom as a standard. Yes, the same carbon-12 we use to define a mole.

Relative atomic mass is defined as the ratio of the mass of an atom to 1/12th of the mass of a carbon-12 atom. 1/12th of the mass of a carbon-12 atom is also defined as one atomic mass unit. The actual value of one atomic mass unit is 1.66 times 10 to the negative 24th grams. So this value is comparable to the actual mass of the atoms.

If we had a balance scale in the micro world, and we used 1/12th of the mass of a carbon-12 atom as scale weights, which means each scale weight has the mass of 1 amu, the relative atomic mass of an atom should be the ratio of its actual atomic mass compared to the above arbitrary standard. So the mass of a carbon-12 atom is 12 amu. And its relative atomic mass is 12.

Next, let's do some numbers to see if you really understand the concept of relative atomic mass. If we know the actual mass of 1 hydrogen atom is 1.674 times 10 to the minus 24th grams, the mass of oxygen atom is 2.657 times 10 to the minus 23rd grams, and 1/12th of the mass of a carbon-12 atom is 1.66 times 10 to the minus 24th grams, please calculate the relative atomic mass of hydrogen atom and oxygen atom. Work on this during the break and I will see you in a few minutes.

Hi, everyone. I'm sure you have got the answer. That calculation is easy. And I just want you to truly understand the concept of relative atomic mass through the calculation that you did. From our calculation, the actual mass of hydrogen and oxygen should be 1 amu and 16 amu. So the relative atomic mass of hydrogen and oxygen is about 1 and 16 respectively. Relative atomic mass is a ratio, so it's just a number and has no unit.

We have already reviewed the concept of relative atomic mass. And this will help us further investigate the relationship between the molar mass of an atom and its relative atomic mass. We already know that the molar mass of carbon is numerically equal to its relative atomic mass, and is 12 grams per mole according to the definition of mole, which means a group of Avogadro's number of carbon atoms is 12 grams.

So what is the relationship between the molar mass of carbon atom and the molar mass of hydrogen, oxygen, or any other atoms? If we could figure out their relationship, we can easily get the molar mass of these atoms, because we already know the molar mass of carbon atom. Let's think about it, and I will see you in a few minutes.

Hi, everyone. Have you found the relationship between the molar mass of carbon and the molar mass of other atoms? For example, hydrogen and oxygen. As we can see here on the screen, we know that the ratio of the mass of 1 hydrogen atom, 1 oxygen atom, and 1 carbon atom is 1 to 16 to 12. Then, what is the ratio of the mass of 100 hydrogen atoms, 100 oxygen atoms, and 100 carbon atoms?

Is it still 1 to 16 to 12? Yes. This ratio will not change as long as the number of hydrogen, oxygen, and carbon atoms is the same. Similarly, the ratio of the mass of Avogadro's number of hydrogen, oxygen, and carbon atoms is also 1 to 16 to 12. Avogadro's number of atoms is 1 mole atoms. So the ratio of the molar mass of hydrogen, oxygen, and carbon is 1 to 16 to 12.

We already know the molar mass of carbon is 12 grams per mole. Obviously, the molar mass of hydrogen and oxygen is 1 gram per mole and 16 grams per mole. See, the molar mass of hydrogen and oxygen have the same value of their atomic mass.

Actually, if we use other atoms, we can draw the same conclusion. The molar mass of any atom is always numerically equal to their relative atomic mass. The only difference is that the relative atomic mass is a ratio. So it has no unit. But the molar mass has a unit, gram per mole.

Here I want you to pay attention to the fact that the relative atomic mass shown on the periodic table is an average relative atomic mass of the isotopes of the element. That's the reason why the relative atomic mass of carbon on the periodic table is 12.01, instead exact 12. 12 is the relative atomic mass of carbon-12 atom. But 12.01 is the average relative atomic mass of naturally occurring carbon, because it has some carbon-13 present.

All right, after knowing the molar mass of atoms, how do we calculate the molar mass of molecules or the molar mass of iron compounds? For example, what is the molar mass of water? What is the molar mass of sodium chloride?

It's easy. Just simply add up the molar mass of all the atoms or ions in the molecules or iron compounds, remembering that there might be more than one atom of each type per molecule. Great, we have already solved the problem of molar mass.

Next, let's see how mole links the invisible micro world to the observable macro world. Think about the following question. What is the mass of 1.204 times 10 to the 24th water molecules. Have a try and I will be right back.

Welcome back. Did you get the answer? How did you get it? According to what we have learned, first, we can convert 1.204 times 10 to the 24th water molecules to its amount of substance by the first conversion factor, NA, which is 2 mole. Then, by the second the conversion factor, the molecular mass of water, which is 18 grams per mole, we can convert the 2 moles of water to 36 grams water.

See, by Avogadro's constant and molar mass, we can easily count the invisible 1.204 times 10 to the 24th water molecules just by measuring 36 grams of water, just as we counted 10,000 beans. I hope you have enjoyed my lesson on two new concepts, amount of substance and a mole.

What we have learned can be summarized by this diagram. Because the elementary entities that make up the substances around us are incredibly small, it is impossible for us to count or measure them one by one. So scientists put 6.02 times 10 to the 23rd, which is also called Avogadro's number of elementary entities, together to form a large group. And the unit of this group is mole.

So if the elementary entities are grouped in moles, then we are able to observe and count them mole by mole. So Avogadro's number is the first the conversion factor. Also, we found out that with molar mass, we could easily translate between the amount of substance in moles and the mass so that we can measure directly in the macro world. Therefore, molar mass here is the second conversion factor.

In summary, with these two conversion factors, amount of substance in moles is like a magic bridge that links the number of invisible elementary entities in the micro world to the measurable mass of substance in the macro world. Thanks for watching my video lesson. I hope all of you had fun and succeeded in learning chemistry.

Hi, thanks for watching my video lesson. And I hope you will get a chance to use it in your class. This lesson is about the concepts of amount of substance and its unit mole. These two concepts are essential in the study of chemistry. However, numerous studies agree that this topic is one of the most difficult topics to teach and learn in chemistry.

And even educators have misconceptions about the concept of mole. This is mainly due to the abstract character of the amount of substance and the mole concepts. Also, the terms of amount of substance and the mole are rarely used in our daily lives, and are unique to science itself. So this technical language is another obstacle standing in the way of learning today's topic.

This lesson is designed to develop and optimize learning teaching strategies to help students understand the two concepts. The teaching learning goals can be achieved by using concrete models, examples, and analogies that are familiar to the students by conducting simple and fun activities, and by adopting technologies to visualize the microscopic world.

This lesson is designed for two-class sessions. And each class session is about 40 to 45 minutes. The key learning objective is to help students understand that amount of substance is used as a bridge to connect the invisible micro world to the observable macro world.

Before beginning this lesson, students should have previous knowledge about atoms and atomic structure, including the concepts of isotopes and the relative atomic mass. They should also know the composition of matter and the meaning of a chemical equation. In addition, they should know how to express a number in scientific notation.

In the opening of the lesson, the students are introduced to the concept of unit by the experience of buying fruits, some large and some very small, which is a familiar experience in their daily lives. Then, in activity one, the students are asked to discuss what they know about amount of substance, and also to measure the weight of a single bean. When I come back and explain the concept of amount of substance and its unit mole, I associate the amount of substance with other basic physical quantities, such as length, mass, and time, quantities that students are familiar with to help them understand the new concept.

Here I need to emphasize that it's common for students, teachers, and even some textbooks to express the amount of substance inappropriately. For example, instead of asking how many moles in 18 grams of water, it is semantically correct to express this as, what is the amount of substance in 18 grams of water? So amount of substance is a basic quantity, and mole is a unit. The meaning of these two concepts is different and they should not be confused with each other.

For the first activity of measuring beans, you can choose any kind of beans that you want, as long as they are small enough so that the weight of one single bean cannot be measured by a usual scale. Or you can do something else for this activity. For example, you can ask students to measure the thickness of a sheet of paper.

The solution is similar. First, measure the thickness of a stack of paper. For example, 100 sheets of paper. And then divide the thickness of 100 papers by 100. These types of activities are designed to help students understand that when dealing with something that is really small in size, it's better to put them together and manage them as a group.

The next activity, activity two, is to identify units that have been created to describe the amount of certain substances in your area. The intention here is to help students understand that amount of substance and its unit mole are defined by humans. And the number of items in a group is also defined by humans according to their own needs.

In the activity three, the students will try to answer how many molecules are there in one drop of water. You can design some other questions for this activity. For example, how many atoms are there in one gram carbon? The goal of this activity is to help students to imagine how small these elementary entities, such as molecules, atoms, ions are.

In activity four, the students are asked to estimate a counting unit for extremely small particles. What I'm asking the students to do is to estimate how many tiny particles, for example water molecules, have scientists put in one mole?

In the lesson, I use a tablespoon and a teaspoon as references. Actually, students can think of anything else in their daily lives to help them estimate the number, such as a water bottle or a mug. Of course, the results of the estimation will be different according to different measuring devices.

For example, if you use a 250 milliliter water bottle to estimate, your estimation about the order of the magnitude of the number of water molecules in one mole of water should be 24. So there is no exactly correct answer to this question. The result depends on what the measuring device you choose to do the estimation. Usually, the range of estimation falls between 22 to 24.

But if students choose a 500 milliliter water bottle for estimation and get a result of 25, that's also fine, because 500 water bottles are also very common in daily life. The purpose here is to encourage the students to think as scientists do and know how to do the estimation by using something common in their daily lives.

The first class session will be done at the end of segment five. At that point, students are asked to watch another BLOSSOMS lesson called, How big is a mole? Do we really understand Avogadro's number? This lesson is designed to help students visualize and imagine just how enormous this Avogadro's number is.

Students can just watch the lesson and don't have to do the activities, or the teacher could present the video lesson in class before the second session of this lesson. As additional homework after the first class session, we have asked the students to answer the following question. How long would it take for the people on Earth to eat one mole of rice, assuming one person can eat 0.5 kilograms rice per day?

To answer this question, students need to know the weight of one single grain of rice, and also the population of Earth. They can find that these numbers by doing some online research. Actually, the weight of one single grain of rice varies with different types of rice. And usually, its weight will fall between 15 milligrams to 25 milligrams. Here I used 20 milligrams as the weight of one single grain of rice and 7 billion for the Earth population, and got to the answer to be about 7 million years.

So your answer might be different depending on what numbers you use. After students learned the definition of mole and Avogadro's number, you may need to remind them that the practical use of a mole is limited to counting elementary entities, such as molecules, atoms, ions, electrons, protons. We don't use it to count objects in our daily life.

Returning to the second session of this lesson, in segment six, the history of Avogadro's number is presented. Actually, students can do some research on this by themselves before the second class session and share the findings with their fellow students during the class.

In activity six, students are asked to answer two questions to deepen their understanding about the concept of mole. The first question is designed to remind the students that when using mole, we should always specify the particles. The second question is designed for the students to practice the conversion between the number of the particles and amount of substance.

In activity seven, counting 10,000 beans is used as analogy to explain how to count one mole of water molecules through Avogadro's number and the molar mass of water. It's much easier for students to understand that idea by referring them back to the counting of beans, which are items in their daily lives that can be observed directly. The goal of activity eight is to let students build the connection between the molar mass of an atom and its relative atomic mass. You don't have to use the same four specimens that I use in the lesson. And you can use what you have in your lab to do this experiment, such as carbon and sulfur powder.

If you don't have any of these materials and are not able to do the experiment in your school, you can give the students the mass of one atom of some element, ask them to calculate the mass of one mole atoms, and then compare the results from their calculation with the relative atomic mass on the periodic table. In the next three segments, segment 9, 10, 11, we review the definition of relative atomic mass first, because this definition is confusing to some students.

However, understanding this definition is essential in order for the students to understand the relationship between relative atomic mass and molar mass. Then we explain that the ratio of the actual mass of one hydrogen atom to one oxygen atom to one carbon atom is equal to the ratio of their relative atomic masses, which is 1 to 16 to 12. The key point here is let students understand that this ratio won't change as long as the number of hydrogen, oxygen, and carbon atoms is the same.

In other words, no matter whether we have one atom of hydrogen, oxygen, and carbon, or 100 atoms of hydrogen, oxygen, and carbon, or even Avogadro's number of hydrogen, oxygen, and carbon atoms, as long as the number of these three atoms is the same, the mass ratio of these three atoms is always 1 to 16 to 12. During the investigation of the relationship between relative atomic mass and molar mass, you may help students to recall and clarify some confusing concepts, such as isotope, mass number, atomic mass, relative atomic mass of a specific isotope atom, relative atomic mass of an element , etc.[INAUDIBLE].

After this class, the students should understand the concept of amount of substance and mole, and will be able to explain why these two concepts are important and how they link the invisible micro world to the observable macro world. They should also be able to do conversions between the number of the elementary entities, amount of substance, and mass by using Avogadro's number and molar mass as conversion factors.

We have included all other materials and resources related to the topic of this lesson on our web page. I would like to thank you again for viewing this BLOSSOMS lesson. And I want to let you know that I had a great time developing it.

I strongly recommend that you watch the other two BLOSSOMS lessons about amount of substance and mole. The links to these two lessons are listed here on the screen and also on the BLOSSOMS website. One is the lesson, How big is a mole, do we really understand Avogadro's number? And the other is lesson on stoichiometry. I hope these three lessons will assist you when you are teaching these topics. Thanks and good luck.

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