Teacher's guide

Teaching/learning goals:

This lesson is designed to develop and optimize learning/teaching strategies to help students understand the two concepts. 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.

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.

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 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.

Prerequisite knowledge:

Knowledge about atoms and atomic structure, including the concepts of isotopes and relative atomic mass; the composition of matter and the meaning of a chemical equation; knowledge of scientific notation.

Time needed for this lesson:

This lesson is designed for two class sessions and each class session is about 45-50 minutes.

Instructions and explanations for the students' activities:

Part 1

Activity 1:

1. Discuss with your fellow students what you know about the term, "Amount of substance".

According to the name of the term, students may have a guess that may refer to the quantity of something. Then guide the students to understand that "Amount of substance" measures the quantity of the elementary entities in a substance.

2. Try to get the weight of one single bean.

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 the students to measure the thickness of a sheet of paper. The solution is similar: first measure the thickness of a stack of paper, e.g.,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.

Activity 2: Discuss your region's unique needs and identify the unit of "amount of certain substance" that is needed in your part of the world.
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.

Activity 3:
1. If 20 drops of water measures about 1ml water (the density of water = 1g/ml) and 1 water molecule weighs 2.99*10^{-23}g, then how many molecules are there in one drop of water?
Answer: *1□□20 □□□□□×1□□□÷2.99×10−23□=1.67×1021□□□□□*

The goal of this activity is to help students imagine how small these elementary entities (molecules, atoms, ions…) are. You can design some other questions for this activity. For example, how many atoms are there in 1g carbon.

2. How many molecules do you think we should put in a group?
This is just a warm-up question for the Activity 4. The students may guess 10^{21} according to the answer to the last question. They will have more hints and think about this question further in the Activity 4.

Activity 4: Take a measuring device that you use to measure water in your daily life and then, according to its measuring range, make an estimate of how many molecules scientists should put in a counting group?
Answer:
If using a teaspoon to estimate,
1 tsp≈*5□□*, 1 water molecule weighs 2.99*10^{-23}g (the density of water = 1g/ml)

5□□1□/□□÷2.99×10−23 □≈1.67×1023, so the molecules in 1tsp of water is about *1.67×1023*

If using a tablespoon to estimate,
1tbsp≈*15□□*, *15□□1□/□□÷2.99×10−23≈5.01 ×1023*, so the molecules in 1tsp of water is about *5.01 ×1023*

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. There is no exactly correct answer to this question. The result depends on what measuring device the students choose to do the estimation. Usually, the range of the estimation falls between 22-24. But if students choose a 500 ml water bottle for estimation and get a result of 25, that's also fine because 500ml water bottles are also very common in daily life.

The purpose of this activity is not to ask the students to get the same number as the one defined by scientists. 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.

Homework for the first class session:

The first class session will be done at the end of Segment 5. At that point, students are asked to watch another BLOSSOMS lesson called "How Big is a Mole: Do We Really Comprehend Avogadro's Number?". Here is the link for this lesson:
https://blossoms.mit.edu/videos/lessons/how_big_mole_do_we_really_comprehend_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 that video lesson in class before the 2nd session of this lesson.

Homework question: How long would it take for the people on earth to eat 1 mole of rice? (assume 1 person can eat 0.5 kg 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 these numbers by doing some online research. Actually, the weight of one single grain of rice varies with the different types of rice and usually its weight falls between 15mg- 25mg. Here **15mg** is used as the weight of one single grain of rice and **7 billion** is used for the earth population.

Answer:
*1□□□×6.02×1023/□□□×15□□×10−3□/□□0.5□□/□□□×365□□□/□□□□×103□/□□×7×109≈7×106*year

Part 2

Activity 6:

1. Calculate the number of oxygen in 2mol O_2.
The answer couldn't be obtained because we don't know the particular type of the elementary entity it asks about. This question is designed to remind the students that when using moles, we should always specify the particles.

2. Calculate the amount of substance of the water that contains $3.612*10^{24}$ atoms.
Answer: 1 water molecule has 3 atoms
3.612×10246.02×1023/□□□÷3=2□□□
This question is designed for the students to practice the conversion between the number of the particles and amount of substance.

Activity7:

First, think about how you would measure 10000 beans. Then discuss how you could measure out 1mol water molecules.

Answer: *10000100/□□□□□×20□□□□□□=2000□*

In this activity, "counting 10000 beans" is used as an analogy to explain how to count 1mol of water molecules through Avogadro's number and the molar mass of water. It's much easier for students to understand this idea by referring them back to the counting of beans, which are items in their daily lives that can be observed directly.

Activity8: Identify the elements in each of the four specimens?

The goal of Activity 8 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 4 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 the experiment in your school, you can give the students the mass of one atom of some elements, ask them to calculate the mass of 1mol atoms and then compare the results from their calculation with the relative atomic mass on the periodic table.

Activity9: If we know the actual mass of one H atom is 1.674×10^{-24}g, the mass of O atom is 2.657×10^{-23}g, and one-twelfth of the mass of a carbon-12 atom is 1.66×10^{-24} g, please calculate the relative atomic mass of H atom and O atom.

Answer: the relative atomic mass of H atom = $1.674\times1.66\times \approx 1$,

the relative atomic mass of O atom $=2.657\times1.66\times \approx 16$

Activity10: What is the relationship between the molar mass of C and the molar mass of H, O or any other atoms?

In activity 9 and 10, we explained that the ratio of the actual mass of 1 H atom to 1 O atom to 1 C atom is equal to the ratio of their relative atomic masses, which is 1:16:12. The key point in activity 10 is let students understand that this ratio won't change as long as the number of H, O and C atom is the same, which is always 1:16:12.

Activity 11: What is the mass of 1.204×10^{24} water molecules?

Answer: 1.204×*10246.02×1023□□□−1×18□□□□=36□*

This question is designed to allow the students to practice the conversion between the number of particles and the mass so that they can deepen their understanding of the concepts of amount of substance and its unit – mole.