How Much Small Is Small?

Hello, I'm Dr. Fadwa Odeh, a chemistry teacher in the chemistry department of The University of Jordan, Amman.
Today, we will talk and think together about a concept you all know and are familiar with. It is "volume". In this universe, there are things we consider big, others we consider small. Sure you have your own concept to compare between big and small things. Also, you have your own lists for the things you consider the smallest and the biggest or the largest in the universe or in your life.
Today, we will think about this concept. We may wonder if the volume, and whether it is large or small, affects the characteristics of the matter. How can we compare between various objects of the same matter according to their volume? If I have an object and make it into different smaller volumes, through cutting or grinding, will this affect its characteristics and usages in our everyday life, even though chemically it is still the same? Now I will leave you for 5 minutes with your

teacher to make your own lists of what you consider biggest and smallest objects in your life. I am sure you have so many things to list and compare. See you in 5 minutes.
Hello again!
I am sure you have your lists ready by now and have had a thorough discussion of the subject. I am also sure these lists contain a variety of things you consider small. Your baby brother or sister or things like that marble you play with may be on the list. It may contain the sand particles you see on the beach or even smaller things. Among the large objects you may have listed a football, a car or a truck, there might be a mountain in your area or even planet earth.
Now, in your classification, what was the principle factor you considered in your lists? On which basis have you classified these objects? By what criterion can we say that a truck is bigger than a car? Or the house is smaller than the mountain?
There must be a criterion you used for such comparisons. We are talking about "volumes", so the units we are using must be unified.

Another question is: In your list, did you add things with dimensions in micrometer? You know that in comparing volumes, the basic measurement is the length unit which is measured in meters. Volumes are usually measured in cubic meter, in case we have a cube like that, for instance.

Note that the volume of a cube volume is Height x Width x Length. The length unit is the same as that of the width, as well as the height, which is in itself a length unit measured in meter, that has multiples and partitions , and it is the conventional unit for measuring lengths. It has multiples and partitions. From its partitions, we have for example the decimeter (0.1 m), the centimeter (0.01 m), the millimeter (0.001 m) and we can go further down. For the multiples of a meter we have the decameter (10 m), the kilometer (1000 m) and we can go even higher up to the giga-meter and the mega-meter.

Did your list contain objects with dimensions in very small parts of a meter like the micrometer and the nanometer. The micrometer is one millionth of a meter, How about things with very large dimensions, did you reach things in mega-meter or the giga kilo meter, i.e. very large things?

We know that volume is cube of the length, especially if I have a mere cube. However if I have a

circle for instance, there are other special rules that link a specific cubic length unit with the volume of the object I have.
Now, I want to inquire about other things. We know that of the very small things in our universe, but are not the smallest atoms are also composed of smaller things such as nucleus and electrons orbiting around it. Even the nucleus is composed of even smaller parts: the protons and neutrons. And even these are composed of smaller things. Let us look to the smallest atom, the Hydrogen atom. You must have studied it in science, chemistry and physics at school.
A hydrogen atom is composed of a proton and an electron orbiting around it. Do you know the length or radius of Hydrogen atom? Note that it's considered a sphere like this marble but so much smaller. We know that the radius of Hydrogen is in angstroms. Angstrom is $1/10^{10}$ of the meter.
Let us imagine that we have a ball with a diameter of e.g., one meter and assume it is one angstrom which is $1/10^{10}$ of the meter, what do you think the size of electron will be, compared to it? We will find the nucleus is 10^{15} times larger, i.e. millions and millions of times larger than the electron. During the next break, I will let you think about something. We know that things can be made as very large or very small. I can have a big balloon and a small one, I can have large

crystals of sugar or very small particles of it as a powder, I wonder; will the volume affect the characteristics and behavior of such things.
The characteristics of the matter differ even if it's composed of the same material e.g. sugar or salt, so what is the difference if I have a crystal of sugar or sugar powder? This is the question that I want you to consider with each other and with the teacher in class, and tell me if the size affects the characteristics of the matter? Does it affect it in a way we can notice and use? See you in a few minutes.
Hello again! Sure you have thought about the question I asked you, namely does the size affect the characteristics of the matter or not?
Let us talk about sugar for example. If I have sugar crystals and touch them with my hand, and then take my hand out to find out that it is empty, there is no sugar stuck on it, while if I touch the sugar powder, some of it will stick to my skin, though they are the same material, i.e. sugar, and the same chemical composition. I put my hand and it stuck on it.
Let us take another example. I have here some chalk which is calcium carbonate and helium. You use chalk all the time in studying or drawing on the wall. We know that calcium carbonate is

insoluble in water.
Let's take some of these big pieces of chalk put it in a beaker. i.e. a glass cup, or any cup you may have, add some water and see what will happen.
Look! As you see, nothing happened; the pieces of chalk are still there in the bottom.
Let's do it in another way. Let's make the chalk pieces smaller in size by grinding, like we grind sugar crystals to make sugar powder for the Ma'mul sweets. As you see, grinding or crushing is used to make particles' size smaller.
We are crushing it now in a better way.
As you see, the sizes are much smaller, some are still bigger but the others are so small. The more I crush the calcium carbonate. i.e. the chalk, the smaller the particles are. Now, it has become smaller.
Let's see what will happen if we add them in water. We put them in another beaker, it is the same material but composed of smaller particles than the chalk used earlier.

I will add some water, and as you see, chalk is still not soluble in water.
We stir the mixture, although it is still not soluble but it forms a suspension that is more homogenous now, but it is still not soluble. If I crush it more, I will have even a more homogenous mixture. The radius of the chalk particles here is in millimeter or parts of it. If it were in nanometer, it will be more homogenous and stable.
You see the mixture is cloudy meaning we don't have solubility but homogenous suspension for a while. If I took a sample of it from any part of the mixture it will give roughly the same concentration. If I take a sample of the mixture, I will find the same distributed number of calcium carbonate.
After stirring, if this was left undisturbed it will take a long time to separate solid from solution because the particles of chalk are smaller. The smaller the particles, the longer time it will take to settle in the bottom.
While this; no matter how much I stir, it will be non homogenous. And the concentration here is different than the concentration here in the bottom.

What is the importance of this? Assume I have a drug that is insoluble like chalk in water, and in drugs, concentration is very important. If I take my portion from the upper region, the concentration will be so small, and if I take it from the bottom region, the concentration will be very high and it may be useless or I might die, for its concentration from the bottom region is so high. So what can be done? I try to make it in so many small particles, so that it may become soluble, which has a longer stability and homogeneity than large particles. Of course, there are more efficient techniques to make drug suspensions and solutions more homogenous and efficient. Let's take milk as an example.

If we get a cup of white milk, we will find that it contains so many things that are insoluble in water such as proteins. A stirred cup of milk is homogenous and will stay so for some period of time since the volume of the insoluble particles is so small. However, if they are left for a long time, the solid particles will start to settle in the bottom. So changing the size will affect the way things behave even though chemically, nothing changed, especially in solutions or mixtures.

We have mentioned that milk is homogenous as it's composed of things that can not dissolve in water e.g. fats. I'm sure you have mixed oil with water. As long as you are stirring, you might have a homogenous mixture but the moment you stop, two layers will start to separate: water and oil again, for they can not mix. Milk is composed of fats and proteins that are huge components. The bigger the chemical compound is, the harder it dissolves in water. We also find calcium and some minerals. All of such, particularly those that are insoluble make a homogenous solution.
If I take a small amount of fresh milk and put it on my skin, like that, we will notice the solid particles like the powder are not soluble and we'll be able to see some.
Why are such simple things homogenous in water, while the larger ones are not, though the chemical formula is one? Of course, concentrations of the various components of milk vary according to the source of milk and how it was treated especially regarding fat concentration. We have milk with so much fat, up to 50%, and there is milk with fat content as low as 1% but in general it is always a mixture of water insoluble materials.

Yet, the insoluble things have very small particles, so that they can be homogenous. So what is the difference between chalk in small pieces here and the one in one big piece? That is the question that I will let you think about. What is the difference between the ground chalk and the chalk in pieces? Why is this homogenous and will take longer time to separate while that is not? What is the difference between this and that? It's the size. How does size affect in such way, when the particles are smaller? This is the question that I will let you think about for a while.
Hello again, I am sure during the time you were busy doing calculations to prove that the smaller a particle is, the more surface area we'll have for the particles that will be exposed to the environment around them, whether it’s air, solution or liquid e.g. water. If I have solutions, the surface area will be bigger. In other words, more molecules will be exposed to this environment and so larger number of molecules will interact.
Let us do some calculations like those you have done during the break.
Suppose we have a spherical particle with a radius of 1 m. R = 1 m

Which means a spherical particle with a radius approximately this big. I want to calculate its mass, volume, and the surface area when the radius is 1 m upon the mass. I wish to take the same mass and divide it into smaller balls and see the ratio of its surface area to its volume.
If we have a ball with 1 kg in weight with a radius of 1 m, let me calculate the volume, we will find out that it is 4.19 m^3. The surface area of this ball, i.e. the exposed area, is 12.56 m^2. The surface area upon the mass is $3 \times 10^{10} – 3$ m^2/kg.
This is the case if the radius is 1 m. Let me make smaller balls with radiuses of 0.1 m, then the volume will be 4.19×10^{10} - $3m^3$, and the surface area for the mass, compared with the first, will be $3 \times 10^{10} – 2$.
In case we decrease the ball's radius from 1 m to 0.1 m. i.e. ten times smaller, we will note that the surface area for the mass will increase by ten folds. If we decrease it more, namely $1 \times 10^{10} – 6$ i.e. 1 micrometer (one of a million of the meter), we will find out that the volume is lessened to 4.19×10^{10} - 18 m3. The surface area of the ball with a radius of one of a million of the meter is 3×10^{10} - 3 m2/kg.

Hence, the smaller the things, the surface area, or the number of particles exposed to the environment, is larger. That's what makes the matter characteristics change whenever the volume does. I may continue decreasing the volume of the matter till I reach one molecule or one atom, Which is then exposed to the environment, just like the Gas case. In such a case, each molecule is alone and single, and every thing has its own characteristics changed whenever the volume of the particles does.
To understand how more interactions will be present when particles of the matter are smaller let's do the following. Since matter is composed of molecules and different volumes are just different collections or aggregations of these molecules, let’s imagine that these beads are molecules and are all aggregated in one particle. See, only a limited number of the molecules are interacting with the environment which are the molecules positioned on the surfaces.
Let’s divide them into two particles of smaller volume. I can see more beads (molecules) so interaction is more.

Let's divide them even more and have yet smaller particles. As you see, the smaller the particles volume is, the more number of molecules get exposed to the environment and hence we'll have more interaction.
Try to do it with different materials like dough for example during the next break. We can get a dough or any thing that can be formed into balls with different volumes and forms. Such will be like molecules. Count them, try to equal them with the big volume, and tell us how many will appear on the surface? And how many can you see? Then try to equal them with small volume, count them and tell us how many will appear on the surface? And how many will not? You will notice that the smaller the volume, the more molecules appear on the surface. I will leave you so as to do this activity. See you in a few minutes.

During the previous sections of the video, we have proved that as particles become smaller, then the surface area of them, exposed to the environment, becomes bigger. Of course this was proved using calculations that we did in the previous segments and also through some demonstrations and shapes. As you all know, big things are just aggregations of small things. For example, protons and neutrons are composed from quarks. Nuclei are composed from protons and neutrons. Atoms are formed from nucleus and electrons orbiting around it. Molecules are formed through the interaction between various atoms. These molecules when are together in various combination will give us larger things like cells. When cells come together, they might form a human being, a tree or so many other things. For example, chalk is an aggregation of calcium carbonate molecules. So when small things come together will give us big things, such as mountains, planets, stars and the whole universe.

From all this, new fields of science and knowledge have emerged such as nanoparticles science. It deals with the formation, characterization, characteristics and applications of small particles in the nanoscale, 1 × 10% - 9 of the meter, and we call it 1 nanometer and up. And since these nanoparticles are so small, it has a huge surface area and hence its characteristics are different. We can use them in very important fields like computers. As you know, computers are becoming smaller and smaller with even higher capabilities because of these nanoparticles. Also in the drug delivery, we use small vehicles (in nanoscale) to carry drugs and deliver them to exact locations in the body.

Notice also that nanoparticles are little bigger than molecules. These nanoparticles are formed by aggregation of number of molecules. These nanoparticles carry their load just like any other compound goes on and distinguishes the position they need to unload in, e.g. a cancer cell. So the size is very important. To determine the characteristics we want, we must first determine the volume. The smaller the volume, the more the characteristics change. For example the electron, it is much smaller than the atom, and it even behaves in a dual way because of its volume. It can behave as a particle but it can also behave as a light beam. See how even the nature of things can change. Thus, in addition to the chemical formation that link the atoms, we notice that if we get big sized matter, it will behave completely differently than the same smaller sized one, Less than the micrometer.
I hope, God willing, you have enjoyed this video and found it useful, and also I hope it triggered your interest in the characteristics of matter, and the most important one is the volume, as well as the chemical formation. Good luck to you all and see you in other videos.

Hello, I would like first to thank you for using this module and I hope, God willing, you and you students will find it useful. What I'm trying to present here are some suggestions on things you can do with the students. Some simple demonstrations and experiments are suggested so the concept will become clearer.

This module deals with the concept of volume and to show that when things become smaller, their behavior and characteristics will change. During the first pause, try to initiate a discussion between you and the students about the things they consider small or big. Let them form lists of their smallest and biggest things. Through these lists you will come to how to compare, measure length, units of length, its divisions, such as the meter, the centimeter, the nanometer, and the multiples, such as the kilo, the mile, the light year. Such things will make the issue hold firmly into their minds. Try to bring measuring devices such a ruler, and ask how to measure a micrometer with it, or try to bring an inch ruler or measuring tape. Also through these lists, try to point out how there are smaller or bigger things. See if they can list some of the smallest like a grain of dust, an atom or even smaller, electrons, protons and neutrons. And the big things, try to discuss with them things bigger than mountains and trucks such as planets, stars and galaxies. This will give them a better understanding for the concept of the volume, and how it affects the characteristics of the matter. It's most important to understand that volumes form a continuous spectrum form biggest to smallest. And there are no borders separating the two, exactly like numbers, small and big, not the smallest and the biggest.

In the second pause, we'll talk about how volume affects behavior. It will be helpful to talk about familiar things such as the volume of various students and how it will influence there behavior and favorites. For example huge students might go to play basketball , smaller might prefer other activities and how it was a factor even in the behavior of humans. Also in animals, for example the elephant and the mouse and how volume affected their behavior. For example the mouse is

composed of millions of cells while the virus is composed of only one cell. The more the cells combine, the bigger the volume.
This module deals with the concept of volume and how the smaller things become, there behavior and characteristics will change. During the first pause, try to initiate a discussion between you and the students and also among them about the things they consider small or big. Let them form lists of their smallest and biggest things. Through these lists you will come to how to compare, measure length, units of length, its divisions, such as the meter, the centimeter, the nanometer, and the multiplications, such as the kilo, the mile, the light year. Such things will make the issue hold firmly into their minds. Try to bring measuring devices such a ruler, measuring tape. Also through these lists, try to point out how there are smaller or bigger things. See if they can list some of the smallest like a grain of dust, an atom or even smaller, electrons, protons and neutrons. And the big things, try to discuss with them bigger things than mountains and trucks such as planets, stars and galaxies. This will give them a better understanding for the concept of the volume, and how it affects the characteristics of the matter. It's most important to understand that volumes form a continuous spectrum from biggest to smallest. And there are no borders separating the two, exactly like numbers, small and big, not the smallest and the biggest.

In the second pause, we'll talk about how volume affects behavior. It will be helpful talking about familiar things such as the volumes of various students and how it will influence there behavior and favorites. For example huge students might go to play football, smaller might prefer other activities and how it was a factor even in the behavior of humans. Also in animals, for example the elephant and the mouse and how volume affected their behavior. For example the mouse is composed of millions of cells while the virus is composed of only one cell. The more the cells combine, the bigger the volume. So volume affects the behavior of living things. Also when looking to humans or trees, we can see they are composed of smaller things like cells. These cells are small, and the larger the species the more cells will contain. But even the cell will be considered small compared to its components such as proteins, fats, water. And how so many interactions and reactions occur in the cell and how the volume of a cell is advantageous. It allowed effective interaction which will shorten time needed for reactions. If the cell is much larger than it is, it will take a long time for reactants to collide and reaction to happen then transfer things around the cell or in and out of it. As you see, the volume of the cell is very important in

facilitating its functions.
In the third pause, the reasons volume affects behavior will be discussed. It will be easier if you worked with the students using objects like equally ssized cubes, from Lego or cardboard. Arrange them as larger cubes and calculate the surface area of the big cube. Then make this big cube into smaller cubes, four and then nine cubes, and calculate the total surface area. It will be easy, since it is a cube, for the Length × the Width × the Height is the length of the side in cubic meters.
In the module I used spheres but you can use cubes- it will be easier for students to calculate volumes and areas. The students will see that the surface area of the small cubes will be larger than one big cube. This means that there are more molecules exposed to the environment leading to more interaction and hence different behavior. Even if these cubes are formed of the same matter, there will be differences in their behavior. This will be a nice exercise for students to do and they can make their own cubes.

In the last break is will be useful to run the same calculations we had for cubes when it is made into spherical shapes like balls or beads and to try to calculate their volumes in nanometers which is 1 times 10 to the power negative nine of a meter which is very close to the size of atoms. The smallest atom is that of hydrogen and it is about one tenth of a nanometer or one Angstrom. This will give the students an idea about how compounds and atoms interact, god's willing. I hope you have gained a lot of knowledge, and that your students now have an idea about the reasons for differences in behavior resulting from differences in volumes.