MITOCW | conservation_of_mass

What do the growth of a plant and the rusting of a truck have in common? Both processes involve mass transfer. In this video, you'll learn how to apply the concept of a control volume and the law of conservation of mass to real-world scenarios.

This video is part of the Conservation video series.

In order to analyze or modify a system, it is important to understand how the laws of conservation place constraints on that system.

Hi. My name is Mark Bathe and I am a professor in the Department of Biological Engineering at MIT.

By watching this video, you will be able to apply the law of conservation of mass to real-world scenarios.

Before watching this video, however; you should have had experience with basic reaction stoichiometry.

In the 18th century, Antoine Lavoisier, a French scientist, showed that there is no overall change in mass when a reaction takes place in a sealed container.

This observation is called the law of mass conservation.

What would Lavoisier say about a plant's growth... ...or a car rusting?

Can conservation of mass be applied to these scenarios?

Of course it can.

By using a conceptual tool called a "control volume," we can more easily apply the law of mass conservation to these scenarios.

What is a control volume? A control volume is a fictitious boundary that separates a system of interest from its surroundings. A control volume is NOT a tangible, solid boundary. Nor does the control volume have to be a specific shape or size. A control volume can transmit energy or mass. A control volume should be seen merely as a tool, and defining a control volume is a matter of convenience. Depending on the question being investigated some control volumes may be more convenient than others.

Before we go back to the growing plant or the rusting car example, let's go through a more visual example to demonstrate the idea of a control volume.

Here we have a sink filling with water. What if we wanted to know how much water is accumulating in the basin? What control volume might we choose to help us answer this question?

Well, what if we were to define the faucet as our control volume? We could look at the flow into and out of the control volume. Would this give us enough information to figure out how much water is accumulating in our basin? No.

What if we defined the whole bathroom as our control volume? We could look at the flow going through all of the plumbing in the bathroom. Would this give us enough information to figure out how much water is accumulating in our basin?

Yes, but we'd also have a lot of information to deal with. This probably wouldn't be the most efficient way to solve the problem.

What if instead we defined the basin itself as the control volume? Ah-ha. We could look at the flow going into and out of the control volume and figure out how much water is actually accumulating in our basin. We have enough information to figure out what we want to know, but not so much information that it is cumbersome to deal with.

Now, we will see how we can use the concept of a control volume and general chemistry knowledge to better understand the application of the conservation of mass to the growing plant and rusting car scenarios.

Back to the growing plant. Let's say that over some period of time, the plant grows and gains a mass of 25grams. Although the plant isn't living in a sealed container, we can still apply the law of mass conservation to the growing plant by specifying a control volume and accounting for the mass entering and exiting that control volume.

Most plants make their food using photosynthesis. The overall reaction for photosynthesis is carbon dioxide plus water plus light energy yields glucose plus oxygen. We'll assume that the plant's mass comes from glucose and it's downstream products.

Now please take a minute to think about what control volume we might specify to apply the law of mass conservation to the plant's growth. [short pause] If we think of the plant as our control volume, we can apply the law of conservation of mass to perform a mass balance on the system. Any mass that is accumulated in our system must equal any mass that entered the system minus any mass that left the system. This is the law of mass conservation.

What mass is entering the control volume? Carbon dioxide and water.

What mass is exiting the system? Oxygen.

Drawing a diagram like this helps us keep track of the information that we know and the information that we don't know.

Note that we ignored the light energy because we are performing a mass balance. We can substitute 25 grams in for the accumulation term in the mass balance equation. Now please pause the video here and see if you can figure out how much carbon dioxide and water entered the system and how much oxygen exited the system. Please continue playing the video to see the worked solutions.

Using basic stoichiometry, we can see that 37 grams of carbon dioxide entered the system...

15 grams of water also entered the system...

And 27 grams of oxygen exited the system.

We can compare these results to our mass balance and see that our inputs minus our output equals the mass gained by the plant. So, the law of mass conservation not only holds, but it gives us important insight into the process of a growing plant. Fantastic!

Now, let's turn to our next example, that of a rusting car.

The car has rusted, but the rust has fallen off of the car, resulting in a decrease in the mass of the car.

Measurements show that the car has lost mass, but has mass really not been conserved?

Let's think about this scenario a little more carefully. What is happening when a car rusts?

Can we write an equation to explain what is happening chemically?

Rusting happens by iron oxidation. This reaction can be written as $3O_2 + 4Fe \rightarrow 2Fe_2O_3$. Measurements show that the car lost 10g of mass. Now please take a minute to think about what control volume we might specify to apply the law of mass conservation to the rusting car.

[short pause] If we define the car as our system or control volume, a concept that we introduced earlier, we can perform a mass balance on the car. Remember, any mass that is accumulated in our system should equal any mass that entered the system minus any mass that left the system.

Our system, the car, lost 10g of mass. This is a negative accumulation.

During the rusting process, did any mass enter our system? Yes, the mass due to the oxygen that reacted with the iron on the car's body.

In our scenario, where a car has rusted and the rust fell off of the car, has any mass left our system? Yes. The mass of the rust, or iron oxide.

Now please pause the video here and see if you can figure out how much oxygen entered the system and how much iron oxide exited the system. Please continue playing the video to see the worked solutions.

Using basic stoichiometry, we can see that 4.3 grams of oxygen entered the system...

and 14.3 grams of iron oxide exited the system.

We can compare this to our mass balance to see that our mass in minus our mass out equals the negative accumulation of mass of our car.

Again, the law of conservation of mass has served as a useful tool to learn something important about our system.

This video illustrated how the law of conservation of mass can be applied to real-world scenarios.

Although real-world scenarios might seem overwhelming at first, we can use a problem-solving tool called a control volume to help narrow our focus. The law of conservation of mass allows us to perform a mass balance on the control volume. In other words, any mass that has accumulated in our system must equal any mass that entered the system minus any mass that exited the system.

This simple idea will provide a basis for understanding systems throughout your time at SUTD and beyond.

FAANTASTIC! (will have to "cut and paste" this audio from earlier)