The Heats of Water

Water has the highest **heat capacity** of all common liquids. That means it has the CAPACITY to accept a lot of heat (or kinetic energy) BEFORE its temperature rises. Why? Those hydrogen bonds. They keep water molecules locked together in a loose bonding that means it takes more energy transfer before their velocity can increase. Think about locking arms with your fellow classmates and then trying to run a race. You'll always be slower than those running separately. We experience different heat capacities when we are outside on a hot day. In this image from the Everglades in Florida, we see two small alligators – reptiles whose internal temperature comes mostly from their surroundings and must move within its environment to locations to minimize its chances of getting overly hot or overly cold. Although the same amount of heat is being transferred by the Sun to all parts of this environment, they do not all have the same temperature. The object with the highest temperature is the rock. It has a LOW heat capacity. The coolest location is the water – it has a high heat capacity, and will remain cool even with lots of added daily heat. Heat capacity and specific heat are very similar terms. They both refer to how much heat is required to raise the temperature of a substance. Heat capacity is a broad term used to describe a large body, like an entire rock or an entire lake. **Specific heat** is used only to refer to 1 gram of the substance in question. The unit used to measure heat is a **calorie**. We all know about calories in the food we eat. But those calories are actually KILOCALORIES – or 1,000 calories. A Big Mac, for example, has 540,000 calories.

The specific heat of a variety of substances is provide here. Notice that the highest is for water. Its value is 1 calorie per gram degree Celsius. Again we have a system of measurement and units developed around water. The definition of 1 calorie is the amount of heat added to 1 gram of water to make its temperature rise 1 degree Celsius. All other specific heats are smaller than 1 (or fractions). Each type of rock has a different specific heat. In this image of the Karajini Gorge in the Pilbara Desert of Western Australia, the temperatures is 116° Fahrenheit. That's hot! If you were in this environment right now, where would you go to cool down? First choice for me? The water. Second? The vegetated areas.

The calories in a Big Mac would raise 540 Liters of water 1 degree Celsius. For 540 Liters of the iron-rich shale in this picture, those same calories would raise the temperature almost 5 times more! That's why if I was walking through this area barefoot (as I was when I ran from the trees to the water), my feet could get seriously fried en route!

Water also has the highest **latent heat** of melting of any common substance. It takes 80 calories of heat to melt 1 gram of ice. Heat that's used to break bonds is called **Latent Heat.** Unlike specific heat, it does NOT change temperature. The calories in a Big Mac would be able to melt 6,750 grams of ice or 6.7 kilograms. A cooler takes advantage of the high latent heat of melting – because the heat used to melt the ice is heat that's removed from your food. The heat you're adding to the ice is **Latent Heat**. The heat removed from your food is **Specific Heat** and it makes it colder.

The heat required to evaporate water is even higher and also one of the highest of any common substance – it takes 540 calories of heat to melt 1 gram of liquid water. The calories in a Big Mac would be able to evaporate only 1000 grams (1 kg or 1 liter) of water.

Sweating takes advantage of the high latent heat of evaporation – because the heat used to evaporate the sweat is heat that's removed from your skin, cooling you off. The heat you're adding to the water is called **Latent Heat** because it is used to break bonds. The heat removed from your skin is called **Specific Heat**, because it is used to change temperature. You'll also notice there that water CAN evaporate at temperatures less than the boiling point, as discussed earlier. However, when it does, it requires even more heat.

This image helps us see how heat or kinetic energy is transferred during the changes of phase from ice to liquid water to vapor. To melt 1 gram of ice takes 80 calories. To warm that gram 1 degree Celsius takes 1 calorie. To warm it 100 degrees to its boiling point takes 100 calories. To evaporate it takes 540 calories. Whatever provided that heat (such as the surrounding air) will be cooler as a result (because it gave up heat). The reverse means taking heat out of the water and giving it to the surroundings. When vapor precipitates as liquid water, 540 calories of heat are given off to the surroundings. When it rains, the surroundings warm up a bit as a result. As liquid water cools, heat is given away to something else. And as water freezes in your freezer, heat is removed and must be transferred somewhere else. You can feel that heat when you reach behind your refrigerator and feel the hot venting air. Note here that we are combining two kinds of heat – latent and specific – to describe this entire process. If bonds are broken with no temperature change, it's latent heat. If temperature changes, it's specific heat. One or the other.

Here's another way to show what happens when ice melts. Notice the X-axis shows increasing addition of calories as you move to the right. The Y-axis shows increasing temperature as you move up. If we start in the lower left hand corner with 1 gram of ice at minus 40 degrees Celsius, we can see that by adding 20 calories of heat, we raise the temperature of ice to its melting point. (The specific heat of ice is ½ a calorie per gram degree Celsius.)

Pause now.

At the melting point, we add 80 calories of heat to break the bonds and melt it.

Pause now.

Then we add another 100 calories to get the liquid water to raise its temperature to its boiling point. (The specific heat of water is 1 calorie per gram degree Celsius.)

Pause now.

At the boiling point, we add 540 calories to vaporize it.

Pause now.

Finally, we add 8.8 more calories to raise the temperature of the resulting steam to 120 degrees Celsius. (The specific heat of steam is 0.44 calories per gram degree Celsius.)

Pause now.

When we add everything up, we see it took a total of 748.8 calories of heat to make the complete change. But most of that heat was required for the vaporization stage.

Notice this picture of an air-conditioning unit. Hot dry air is blown over a pan of water. The hot dry air evaporates water, but to do so it takes 585 calories per gram (since the water is cooler than its boiling point). Where is that heat coming from? The air? What happens to the air as a result? It cools down. In fact, 1 gram of it cools down for every calorie it loses. That's a lot of cooling of a lot of air that can happen for just a little evaporation.

The high latent heat of vaporization of water has a big impact on world weather and climate systems. Water, in its evaporated form, is storing 540 calories of heat per gram. That heat is given off to the surroundings when the water precipitates back as rain. Water also affects the density of air. As water molecules evaporate, they push away and displace the nitrogen (N_2) and oxygen (O_2) molecules that dominate air's composition. But water weighs less than nitrogen or oxygen molecules – almost half as much. So air rich in water is less dense than dry air.

Pause now.

For more information and more detail, continue on to the next video in this series.

[End credits]

Seawater Physical Properties Series:
Part I: Water Molecule Shape
Part II: Water Phases
Part III: Water Density
Part IV: Heats of Water

Part V: Light, Viscosity, & Pressure
Part VI: Heat Transfer

Heats of Water
Geoscience Video Tutorial
Produced by Katryn Wiese
City College of San Francisco

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