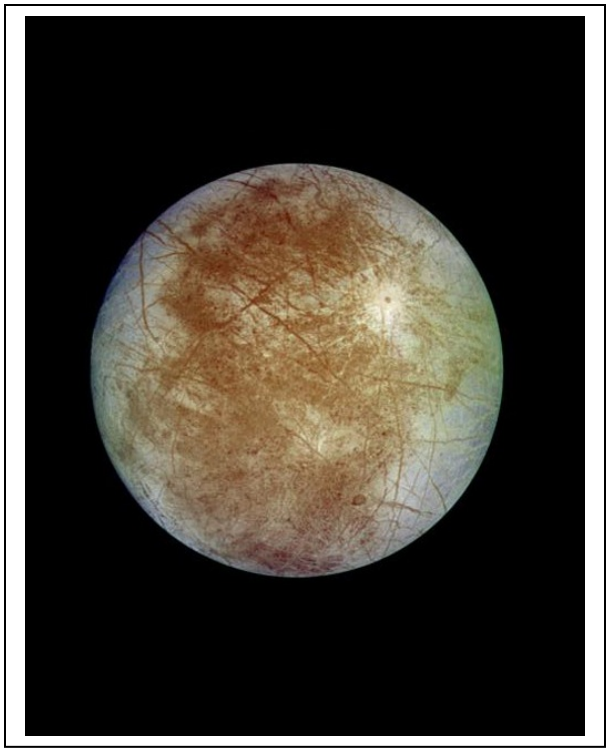
Ice or Water?



There are no known extremophiles that can exist at a temperature lower than the freezing temperature of water. It is believed that liquid water is a crucial ingredient to the chemistry that leads to the origin of life. To change water-ice to liquid water requires energy.

First, you need energy to raise the ice from wherever temperature it is, to 0 Celsius. This is called the Specific Heat and is 2.04 kiloJoules/kilogram C

Then you need enough energy added to the ice near 0 C to actually melt the ice by increasing the kinetic energy of the water molecules so that their hydrogen bonds weaken, and the water stops acting like a solid. This is called the Latent Heat of Fusion and is 333 kiloJoules/kilogram.

Let's see how this works!

Example 1: You have a 3 kilogram block of ice at a temperature of -20 C. The energy needed to raise it by 20 C to a new temperature of 0 C is Eh = 2.04 kiloJoules/kg C) x 3 kilograms x (20 C) = 2.04 x 3 x 20 = 122 kiloJoules.

Example 2: You have a 3 kilogram block of ice at 0 C and you want to melt it completely into liquid water. This requires Em = 333 kiloJoules/kg x 3 kilograms = 999 kiloJoules.

Example 3: The total energy needed to melt a 3 kilogram block of ice from -20 C to 0C is E = Eh + Em = 122 kiloJoules + 999 kiloJoules = 1,121 kiloJoules.

Problem 1 - On the surface of the satellite Europa (see NASA's Galileo photo above), the temperature of ice is -220 C. What total energy in kiloJoules is required to melt a 100 kilogram block of water ice on its surface? (Note: Calculate Eh and Em separately then combine them to get the total energy.)

Problem 2 - To a depth of 1 meter, the total mass of ice on the surface of Europa is 2.8×10^{16} kilograms. How many Joules would be required to melt the entire surface of Europa to this depth? (Note: Calculate Eh and Em separately then combine them to get the total energy. Then convert kiloJoules to Joules)

Problem 3 - The sun produces 4.0×10^{26} Joules every second of heat energy. How long would it take to melt Europa to a depth of 1 meter if all of the Sun's energy could be used? (Note: The numbers are BIG, but don't panic!)

Problem 1 - On the surface of the satellite Europa, the temperature of ice is -220 C. What total energy is required to melt a 100 kilogram block of water ice on its surface?

Answer: You have to raise the temperature by 220 C, then
E = 2.04 x 220 x 100 + 333 x 100
= 44,880 + 33,300
= 78,180 kiloJoules.

Problem 2 - To a depth of 1 meter, the total mass of ice on the surface of Europa is 2.8 x 10^{16} kilograms. How many joules would be required to melt the entire surface of Europa to this depth?

Note: The radius of Europa is 1,565 km. The surface area is 4 x π x $(1,565,000 \text{ m})^2$ = 3.1 x 10^{13} meters^2. A 1 meter thick shell at this radius has a volume of 3.1 x 10^{13} meters^2 x 1 meter = 3.1 x 10^{13} meters^3. The density of water ice is 917 kilograms/m^3 ,so this ice layer on Europa has a mass of 3.1 x 10^{13} x 917 = 2.8 x 10^{16} kilograms.

Energy = (2.04 x 220 + 333) x 2.8 x 10^{16} kg
= 2.2 x 10^{19} kiloJoules
= 2.2 x 10^{22} Joules.

Problem 3 - The sun produces 4.0 x 10^{26} Joules every second of heat energy. How long would it take to melt Europa to a depth of 1 meter if all of the sun's energy could be used?

Answer: Time = Amount / Rate
= 2.2 x 10^{22} Joules / 4.0 x 10^{26} Joules
= 0.000055 seconds.