We will be spending this course studying thermodynamics, which is the branch of physics that deals with the physical properties of matter and the laws that govern the properties of matter. Today we will be discussing what *kinds* of properties matter can have.

I'd like you all to start by pouring yourself a cup of water. I'll give you a moment to go to your kitchens. Then in your small groups I'd like you to brainstorm a list of all the properties that cup of water might have. Please limit yourselves to properties of the *water itself* , omitting any properties of the cup or the room around you.

Solution Here is a non-exhaustive list of properties that students might come up with:

Mass

Volume

Density

Temperature

Pressure

Internal energy

Kinetic energy

Potential energy e.g. gravitational

Mass energy i.e. mc^2

Entropy

Number of water molecules

Number and kind of ions, atoms, and molecules dissolved in the water

Concentration of ions or molecules dissolved in the water

Chemical potential *students probably won't come up with this, and we won't use it in this class...*

pH

Height

Shape

Center of mass i.e. the vector location of the center of mass

Moment of inertia

Angular momentum

Velocity

Surface area

Magnetization Or magnetic dipole moment. It's almost always pretty close to zero, but not quite.

Polarization If you apply an electric field, it might be quite non-zero, since water has a crazy-high dielectric constant.

Electric field Or magnetic field, or electrostatic potential.

Surface tension

Phase i.e. liquid

Viscosity

Compressibility

Electrical charge

Magnetic charge Why not? Zero!

Each of the thermodynamic properties that we can describe as a property of a glass of water are what we call *state variables*. What this means is that the "state" of the water defines the variable, independent for instance of when or where that water is.

Furthermore, thermodynamics (in this class, anyhow) describes the properties of materials, so details like its shape we will not consider to be thermodynamic variables. It *is* possible to apply thermodynamics to, for instance, surfaces, but we will not deal with that in this class.

Drinking half If you drink half of your glass of water (feel free to do so), how will each of your properties change for the water that remains in the glass?

Solution

Mass Cut in half

Volume Cut in half

Density Same

Temperature Same

Pressure Same

Internal Energy Cut in half

Kinetic energy Probably cut in half?

Mass energy Cut in half

Entropy Cut in half

Number Cut in half

Electrical charge Cut in half

Magnetic charge Cut in half

pH Same

Concentration same

Surface tension same

Electric field same

Magnetization same (although total dipole moment would cut in half)

Polarization same

Viscosity same

Compressibility same

Phase same (but not intensive, because it doesn't have a numerical value)

Shape different

Height different... half if the cup is cylindrical

Area different

Center of mass different

Moment of inertia different (except that on one axis it might be half, if your cup is a cylinder)

Angular momentum different (unless it's zero?)

There are two possibilities that account for most of our properties: most are either unchanged, or will be cut in half. The ones that are cut in half are called *extensive*, and the ones that remain the same are called *intensive*. In this class, we will focus on these "*bulk*" properties. By "bulk" here, I mean properties of the material itself, in contrast to properties, for instance, of the surface of the material. One could also consider surface or linear properties using thermodynamics (like surface tension or surface area), but that is beyond the scope of this course. Here are some of the thermodynamic properties:

intensive density, temperature, pressure, pH, magnetization, polarization, electric field, magnetic field, concentration, viscosity, compressibility

extensive mass, volume, internal energy, entropy, number, charge

While technically kinetic energy or gravitational potential energy could be considered extensive, when talking about thermodynamics we generally restrict ourselves to properties that are independent of the position or velocity of the material as a whole. While the surface tension is indeed a true intensive thermodynamic quantity, it is a property of the surface, not the bulk material. e.g. the surface tension will change if the surface is in contact with a different material (which is why a meniscus forms).