1 "Squishability" of Water Vapor

Working in small groups (2 or 3 people), solve as many of the problems below as possible. Try to resolve questions within the group before asking for help. Each group member should then write up solutions in their own words.

The contour map represents measurements on a kilogram of water vapor in an insulated piston (a cylindrical thermos with a moveable top).

Estimate the "Squishability": Imagine a thermodynamic quantity, the *"squishability"*, which is the negative rate of change of the volume of a fluid as the pressure changes.

Pick a point on the contour map and estimate the squishability of water vapor:

1. with *temperature* held constant

2. with *entropy* held constant

Experimental Design: Design an experiment to measure the squishability of water vapor at constant *temperature* and describe your experiment. What data would you collect and how would you use it to calculate the squishability?

> Instructor's guide **Defining the Experiment:** Students should describe what they are going to change, measure, and hold constant and the physical method they would use for each of them.

In your experiment, what variables are you considering to be independent? What variables are dependent?

> Instructor's guide **Discussion: Variables in Thermodynamics** Students typically will say that the independent variable is the one that you change, and the dependent variable is the one that you measure. In thermodynamics, variables that are held constant are often considered independent because you may be able to perform the experiment again at a different constant value.

Consider Other Experiments: What would happen if you tried to measure the squishability with *both* temperature and entropy fixed? Alternatively, what would happen if you tried to measure the squishability in a container that cannot change size?

> Instructor's guide **Answer:** Once two thermodynamic variables are fixed, the state is fully determined so changes cannot be measured. **Answer:** Squishability is related to the change in volume, so an experiment to measure this quantity must incorporate a change in volume.

Instructor's guide SUMMARY PAGE

Goals:

- The value of a derivative depend on what you hold constant (you get different values if you hold T or S constant.)
- Derivatives are ratios of small changes.
- On this graph $(\partial V/\partial p)_S$ is a slope; $(\partial V/\partial p)_S$.

Time Estimate: 30 minutes

Tools:

- Squishability contour map
- Student handout for each student
- A personal or shared writing space for each student to write/draw/sketch.

Intro:

- No intro is needed

Whole Class Discussion:

- On this graph $(\partial V/\partial p)_S$ is a slope; $(\partial V/\partial p)_T$ is not.
- **Discussion: Extensive vs. Intensive** Does the squishability depend on how much water vapor you have? Yes - it is extensive. Note: we've invented squishability, but it is similar to *compressibility*, $-\beta = \frac{1}{V}\frac{dV}{dP}$, an intensive quantity.