1 Instructor's Guide

1.1 Prerequisite Knowledge

- The ability to interpret partial derivatives.
- The ability to physically interpret partial derivatives.
- Students should be familiar with the thermodynamic definition of entropy.

1.2 Introduction

Little introduction is necessary for this activity; however, the first Name the experiment activity should be performed before entering this Name the Experiment activity. Be sure to state to the groups that they must measure the partial derivatives they are given for a rubber band, providing both a description and a picture of their experiment.

Student handout Your group will be given one of the following partial derivatives:

$$a)\quad \left(\frac{\partial S}{\partial T}\right)_V \quad b)\quad \left(\frac{\partial T}{\partial S}\right)_p \quad c)\quad \left(\frac{\partial S}{\partial V}\right)_T \quad d)\quad \left(\frac{\partial p}{\partial S}\right)_V \quad e)\quad \left(\frac{\partial S}{\partial p}\right)_T \tag{1}$$

$$f)\quad \left(\frac{\partial p}{\partial S}\right)_T \quad g)\quad \left(\frac{\partial T}{\partial S}\right)_V \quad h)\quad \left(\frac{\partial V}{\partial S}\right)_T \quad i)\quad \left(\frac{\partial V}{\partial S}\right)_p \quad j)\quad \left(\frac{\partial S}{\partial T}\right)_p \tag{2}$$

In your group, design an experiment to measure this derivative. Draw a sketch of the apparatus and describe how to convert directly measured data into a numerical value for the derivative.

If you finish with your derivative, you can try designing an experiment for the next derivative in the list.

For this activity we have just four partial derivatives:

Heat capacity measurement $\left(\frac{\partial S}{\partial T}\right)_V$ $\left(\frac{\partial S}{\partial T}\right)_p$

Isothermal (challenging) $\left(\frac{\partial S}{\partial V}\right)_T$ $\left(\frac{\partial S}{\partial p}\right)_T$

The first two derivatives are "simple" heat capacity measurements, and the second two are extremely challenging.

If a group finishes their experiment early, have them create an experiment for a more challenging partial derivative.

1.3 Student Conversations

- The heat capacity derivatives (the derivatives with respect to T) are very similar to the experiment students did in the [[courses:activities:eeact:eeice|ice calorimetry lab]], and students often recognize this, which provides a nice review and synergy, and gives students who weren't solid on that lab previously a chance to feel more comfortable with it.

- The two isothermal derivatives are very challenging, and can serve as a motivation for why we care about the derivative tricks that students hate in thermodynamics: it's great to be able to write a hard-to-measure quantity in terms of an easy-to-measure one. This is precisely what students do in the [[courses:activities:eeact:eeice|next name-the-experiment activity]], so this difficult problem can provide a good foreshadowing.
- Some groups **are** able to find experiments for the isothermal derivatives in this activity. Student solutions most often involve the use of a thermostat combined with a measurement of how much heating that thermostat required. Another student solution involves using ice water to maintain the temperature and then measuring how much water was converted into ice or vice versa.

1.4 Wrap-up

Have each group present their experiment. If any groups had a difficult time creating an experimental setup, have other students state any ideas that they would have for measuring the partial derivative. Mention that the partials that have terms of entropy in them or the constant are difficult to measure directly, and that there are ways of measuring a different partial derivative as an alternative to ones with entropy in them. This comment is a good precursor to the Maxwell relations. Here is a [[whitepapers:narratives:entropy|narrative]] for this activity (the second name the experiment).