Stat Mech (PHYS 370) PS 2

Fall 2024 v1.0

As we explore heat, energy, the ideal gas law, and (soon) enthalpy we are getting our toes wet in thermodynamics. In the coming week we move on to foundations of statistical mechanics thinking including thinking about large numbers and ways of assembling systems from many elements.

Reading:

- Chapter 1 So far we have discussed pages 1 - 32 and pages 37 - 39. We will skip pages 41-47 for now. Read pages 33-35 on enthalpy for Tuesday
- Chapter 2

Problems: All referenced problems are in Schroeder. Solutions are due on Thursday September 12 at the beginning of class.

(1) 1.20 The basis of one way to separate U-235. Explain how this method might work in a gas centrifuge.

(2) 1.34 PV transitions

(3) 1.38 Bubbles, energy and volume...

(4) 1.40 Expanding our model for the atmosphere

(5) 1.41 Calorimetry

(6) 1.45 On why the partial derivative notation might be a good idea

(7) 1.48 A snow melt Fermi problem - feel free to use round numbers but take care!

(8) 1.50 and part (g) The College burns about 24 million ft^3 of natural gas, which is about 93% methane, annually for heating. Let's assume that the College's supply is 100% methane. What is the College's 'carbon footprint' due to the combustion of this natural gas, i.e. the number of metric tons of CO_2 produced? HINT: Please note that the enthalpies of formation are given from elements in their most stable states, i.e. H_2 rather than H.

(9) 1.58 and part (b) The R-value for an insulating layer is defined as

$$R = \frac{\Delta x}{k_t},$$

the thickness over the thermal conductivity. Find the R-value for the air described in 1.58. Express your answer in SI units. NB: These are not the units used in North America! See (b) of 1.57 and below for more on that unit.

(10) In this problem we'll make an estimate of the conductive heat loss of a house in Clinton NY during a cold winter day. I have posted the spreadsheet "box_house" with the house geometry and energy pricing data on the course website.

The "R-value" characterizes the quality of insulation and A is area of the building component, wall, window, etc. It enters the (Fourier) equation for heat flow in conduction as

$$\frac{dQ}{dt} = -\frac{A}{R}\Delta T,$$

as you saw in the last problem. Please assume an R-values for a wall of $R = 3.0$ K m^2/W, for windows $R = 0.081$ K m^2/W, roof for $R = 5.0$ K m^2/W, and floor $R = 0.4$ K m^2/W. Let's assume the basement under the floor has a constant temperature of 12.8°C. In case you are familiar with them, the usual US unit is 5.67 times this SI value. These are entered in the spreadsheet.

Please use modify (and save!) the spreadsheet for your calculations. It will be used for later problems.

(a) Assuming an interior temperature of 65° F and an average (cold!) exterior temperature of 15° F compute the rate of energy loss through the whole house.
(b) Compute the energy lost in this cold day. Please express your results in kWh.
(c) Estimate the cost of the required heating using all electric and all natural gas. Which one is cheaper?

Submit a printout of your spreadsheet with your solution.