EART 265 Problem Set 3

Same instructions as for previous problem sets. Due Thurs Mar 1 in class.

1. Peclet Number [S]. We want to conduct experiments with Pe = 0.1 and a velocity of 1 cm/s. However, the real experiments are meant to use a diffusing (and expensive) solute in liquid. Since heat is cheap, we will run preliminary test experiments using temperature diffusion instead. What characteristic velocity should we select to make sure these experiments are applicable to the real ones?

2. Hairy ape, again [S]: If a hairy ape goes jogging, what is the maximum depth of hair (i.e. distance from the skin to the top of the hair layer) the ape can have before heat loss by perspiration is unable to keep up with heat generation? Assume that water vapor can not be transported by advection within the hair layer.

3. Air quality [L]: Your lungs allow oxygen to enter the blood stream, while removing CO2. This transfer happens in small structures in your lungs called alveoli. Make a table with the estimated deposition efficiency of particles with diameters of 10 nm, 30 nm, 100 nm, ...10 µm. If you were the EPA, what particle size range would you regulate to protect human health?

4. Evacuate? [M]: You accidentally spill a large flask of room temperature organic solvent whose label tells you that the boiling temperature is 300°C. You read that breathing this solvent is hazardous at air concentrations above 100 parts per million. Do you go ahead and clean up the spill or leave the room and call Environmental Health and Safety?

5. Heat or mass transfer [L]? The picture below illustrates a cloud drop of diameter \( d \approx 20 \) µm within which (that is, in the aqueous phase) an exothermic reaction occurs: \( X + O_3 \rightarrow XO + O_2 \) (where \( X \) is some undefined molecule). The heat of reaction will be called \( \Delta H_x \) and has units of J/mol (where mol represents either moles of \( X \) or \( O_3 \), since they react in a proportion of one-to-one). The ozone \( O_3 \) diffuses from the surrounding air, where it has a concentration of 50 ppb. Assume the ozone diffuses across a boundary layer of thickness \( d \). Estimate the cross-over value of \( \Delta H_x \) where the control of the reaction switches from the supply of ozone (low \( \Delta H_x \)) to the ability for the drop to eliminate waste heat (high \( \Delta H_x \)). Note that a typical heat of reaction is 100 to 300 J/mol. Would this cross-over value be bigger or smaller if \( d \) were larger? Explain.

6. Devise your own S-class problem related to mass transfer, and provide the answer.

Figure 1: Cloud drop schematic