AOSC 434: Air Pollution

Homework Set #2

Due: Feb. 23, 2021

NAME:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. (2 points) Vertical mixing in the atmosphere can improve air quality.

a) Plot with Excel, or on suitable graph paper and in ink, the temperature of a parcel of air moving from 0 to 5 km altitude if the temperature changes according to the dry adiabatic lapse rate, o, and the surface temperature is -10, 0, +10, and 20°C. In other words construct a primitive atmospheric thermodynamic diagram. (You may also use your Pseudo-Adiabatic Diagram or one downloaded from the web.)

b) Plot, on same graph, the observed lapse rates from the following balloon temperature soundings:

|  |  |  |  |
| --- | --- | --- | --- |
| Altitude (km) | Monday (oC) | Tuesday (oC)  | Wednesday (oC) |
| 0  | 10.3  | 3  | -5.8 |
| 0.1  | 9.4  | 2.1  | -4.9 |
| 1.0  | -0.2  | -6.8  | -15.0 |
| 1.1  | -1.1  | -6.0  | -14.1 |
| 2.0  | -10.5  | -17.1  | -20.2 |
| 2.1  | -11.2  | -17.0  | -20.7 |
| 3.0  | -22.9  | -27.2  | -25.3 |
| 4.0  | -32.8  | -37.0  | -36.0 |

c) Identify the observed lapse rates and indicate where the atmosphere is stable, neutral, or unstable with respect to vertical motions. Assume that the air is unsaturated everywhere.

d) For a constant source of local pollution located at the surface, which day is likely to have the worst air quality? Why?

**2.** (1 point) Calculate the equivalent blackbody temperature of the Earth assuming a planetary albedo of 0.1. Assume an incident solar flux of 1368 W/m2 on a flat surface facing the sun. Remember that the sun illuminates the disk of the Earth not the whole surface of the sphere.

**3.** (3 points) The oxidation of SO2 to SO3 and ultimately to H2SO4 is important in acid rain formation. For the following reaction, important for power plant effluent, calculate the equilibrium constant at room temperature and find the temperature at which the equilibrium constant is unity. Assume changes in enthalpy and entropy are independent of temperature. Note that the appropriate "units" for the concentrations used in a gas-phase equilibrium constant are partial pressure in atm.

2SO2 + O2 $⇄$ 2SO3

Hfo (SO2) = -70.96

Gfo (SO2) = -71.79 kcal/mole

Hfo (SO3) = -94.45

Gfo (SO3) = -88.75 kcal/mole

**4.** (3 points) To produce smog, NO must be converted to NO2. What is the *initial* rate of production of NO2, d[NO2]/dt, in ppm/min for the following reaction at the two initial NO mixing ratios given? Assume STP and the usual molecular oxygen mixing ratio of air, that is 21%. Look at the functional relationship of NO in the rate equation, and explain why this reaction is considered important only for concentrated exhaust gases, and not for the free troposphere.

2NO + O 2 → 2 NO 2

k = 3.3x10-39 exp (530/T) cm6 molecules-2 s-1

[NO]i = 200 ppm; 200 ppb

Hint: At STP there are 2.7E19 molecules cm-3 of air. Also see Finlayson-Pitts & Pitts Ch. 7 for help. You can change either the units of the concentrations or of the rate constant.