PHYS/OCEA 4595 Atmospheric Chemistry Quiz 1, October 2, 2019

Helpful Constants:

1 hPa = 100 Pa = 100 N/m^2
gravitational acceleration g = 9.80 m/sec^2
radius of the earth R = 6400 km
mean molecular mass of air M_a = 28.96 g/mole

1. The mixing ratio of oxygen has been measured at several locations around the globe since about 1990. In combination with carbon dioxide measurements, they can be used to estimate the net global uptake of carbon dioxide over the land. This argument can be made using a diagram. In this diagram, let the vertical axis refer to the mixing ratio of oxygen and the horizontal axis refer to the mixing ratio of carbon dioxide. A line in the diagram can then refer to the evolution of (CO_2,O_2) over time. The diagram should include the following:

(i) An arrow roughly representing the net change in (CO_2,O_2) over the past 30 years. (6 points)

(ii) Three arrows representing the the main processes affecting the evolution of (CO_2,O_2) over the past 30 years. Label each of these three arrows. The slopes of the arrows should be roughly consistent with the stoichiometry of the process in terms of how it affects O_2 and CO_2. You can assume that the vector sum of these three processes is equal to the net observed change. (8 points)

(iii) Of the three main processes affecting (CO_2,O_2), which is considered to be most well characterized? (4 points)

2. We discussed a calculation showing that, in principle, the ocean could uptake all but 3 % of the carbon dioxide emitted by fossil fuel burning. However, this calculation made two assumptions which, in practice significantly restrict the ability of the ocean to uptake carbon dioxide. What are these two assumptions? (8 points)

3. Plants require nitrogen, but are unable themselves to break the N_2 bond. What are the two main natural mechanisms by which they are able to obtain nitrogen in a form they can assimilate? (4 points)

4. (i) When CO_2 dissolves in the ocean, it can assume one of the following three chemical forms: $CO_2 \cdot H_2O$, HCO_3^-, or CO_3^{2-}. Make a plot of the relative contribution of each of these three forms to the total $CO_2(aq)$ as a function of ocean pH. Indicate on this diagram the current pH of the ocean, and therefore, the dominant form of $CO_2(aq)$. (10 points)

(ii) Fossil fuel emissions of CO_2 are increasing the concentration of dissolved CO_2 in the ocean. Is this expected to increase or decrease ocean pH? Explain using relevant chemical reactions. (6 points)

(iii) This change in pH has an important impact on the ability of the ocean to uptake additional dissolved CO_2. Explain. (4 points)

5. This question involves setting up a two box model of the troposphere and stratosphere. The tropopause occurs at 150 hPa. The surface is at 1000 hPa. All atmospheric mass is considered to be in the troposphere or stratosphere. The first order rate constant for the transfer of mass from the troposphere into the stratosphere is $k_{TS} = 0.135\, yr^{-1}$.
N_S : number of moles in the stratosphere
N_T : number of moles in the troposphere

(i) Solve for N_S and N_T. (10 points)

(ii) Solve for the first order rate constant for the transfer of air from the stratosphere to the troposphere (k_{ST}). (8 points)

(iii) What is the mean lifetime of an air parcel in the stratosphere with respect to transport to the troposphere? (4 points)

(iv) The mixing ratio of a CFC is 200 pptv in the troposphere and 150 pptv in the stratosphere. Solve for $N_{CFC,T}$ and $N_{CFC,S}$, the number of moles of the CFC in the troposphere and stratosphere respectively. (4 points)

(v) What is the rate of change of the CFC in the stratosphere (in pptv/year), taking into account transport from the troposphere, transport to the troposphere, and chemical loss. The first order loss rate for the chemical loss of the CFC in the stratosphere is $k_L = -0.1 year^{-1}$. (12 points)

(vi) If the CFC is increasing in the troposphere at a rate of 25 pptv/year, what is the rate of emission (in moles/year) of the CFC into the troposphere? Take into account transport to and from the stratosphere. Assume that there is no chemical destruction of the CFC in the troposphere. (12 points)