Atmospheric Composition and Chemical Processes (ACCP)

NS-MO405M

Retake Exam 1 – 2014-2015

Two quantitative questions
General understanding questions count from first exam

Please write your name and student number on each sheet!!!!!

Read all the questions carefully.

NO OPEN BOOK EXAM!
You need a calculator.

Name: ________________________

Student number: ________________________

ACCP herdenkamen 2015

1) (9 Pt) Estimating global OH concentrations

The temporal and spatial trends of methyl chloroform (CH_3CCl_3, abbreviated as MCF) have been used to estimate global scale OH levels, because the main sink of MCF is the reaction with OH. However, MCF is one of the compounds that transport Cl to the stratosphere, and therefore its production was stopped under the regulations of the Montreal protocol. When the protocol was fully effective, the MCF mole fraction decreased from ~100ppt in 1996 to ~20 ppt in 2005.

$k_{MCF+OH} = 10^{-14}$ cm^3 molec^{-1} s^{-1}

molar mass of MCF: M_{MCF} = 133.5g/mol

molar mass of air: M_{air} = 29g/mol,

total mass of atmosphere is $m_{atm} = 5.1*10^{21}$g

a) 1 Pt. From the observed rate of decrease between 1996 and 2005 calculate a rough estimate of the global average concentration of OH.

b) 2 Pt. Before the Montreal protocol, in 1985, the atmospheric mole fraction of MCF was 120 ppt and the observed trend was 4 ppt/yr. Calculate the total annual emissions in 1985 (in Tg MCF/yr) and the source-sink imbalance in 1985.

The Secret Atmospheric Science Fiction Project (SASFP) has announced that in order to replace MCF as indirect tracer of global OH, they started in 1990 to secretly release a new tracer into the atmosphere that has no adverse atmospheric effects but reacts with OH with the same rate coefficient as MCF. This tracer, called X, with Molar mass M_X= 116 g/mol, was constantly released at a rate of 500 Gg/yr from secret locations in the NH, and is now in steady state.

c) 1 Pt. What is the global average steady state mole fraction of X, assuming that the OH levels have not changed over the last two decades?

d) 3 Pt. An additional important question that the SASFP can now answer is the distribution of OH between the northern and southern hemisphere. They announced by press release that the OH is exactly the same in both hemispheres.
Given this result, derive equations for the reservoir of X in the SH and NH, respectively, as a function of P and first order rate coefficients k_c for chemical removal and k_{ex} for inter-hemispheric exchange (no numerical solution necessary).

e) 2 Pt. Under normal atmospheric conditions (radiation, O_3, H_2O), calculations show that it is not possible to form enough OH from O_3 photolysis to sustain the amount of OH that you calculated in part a). Indeed, it is well-known that OH is recycled back from HO_2 via the reaction HO_2 + NO. This recycling of OH is thus dependent on NO_x levels. Sketch the dependence of OH levels (y axis) on NO_x (x axis) qualitatively and explain the dependence by writing down the most important reactions of the HO_x radicals in very low, medium and high NO_x conditions.

(9 Pt.) Radiation balance of the earth

Consider a radiation model of the earth's atmosphere, which consists of two isothermal layers, each with absorptivity $a_S = 0$ for short-wave solar radiation and $a_L = 0.5$ for long-wave planetary radiation. Assume that the surface emits as a black body in the long-wave range. The incoming solar radiation is $S_0 = 1380$ W/m^2, the planetary albedo is $A = 0.3$.

a) make a diagram of the energy fluxes **(2 Pt.)**

b) show that the **outgoing** (upward) radiation of planetary radiation is E/3 for the top layer, E/2 for the bottom layer and 5E/3 for the surface of the planet, where E is $S_0/4*(1\text{-}A)$ **(3 Pt.)**

c) Show explicitly that the "effective temperature" of the planet is the same as it would be without atmosphere (by summarizing all the energy fluxes leaving to space)**(1 Pt)**.

Generalize the problem and consider the radiation balance of an atmosphere with a two number of layers, each of which is isothermal, transparent to solar radiation ($a_S = 0$), and absorbs the fraction a_L of longwave radiation incident on it from above or below.

d) Show that the **outgoing** (upward) radiation emitted by the topmost layer is $a_L E/(2 - a_L)$ where E is the total planetary radiation emitted to space as in b. Hint: consider only the fluxes that affect the top layer and summarize all fluxes from below **(3 Pt)**.