

**Exercise 1:**

General questions/short exercises:

- a) Are the following loss processes first-order?
  - A. Uptake of CO<sub>2</sub> by the biosphere
  - B. Photolysis of gases in the stratosphere
  - C. Scavenging of aerosol particles by precipitation
- b) Consider a 2-box model with the two boxes being the troposphere (1000-150 hPa) and the stratosphere (150-1 hPa). The lifetime of air in the stratosphere is 2 years. What is roughly the lifetime of air in the troposphere?

**Exercise 2:**

Briefly comment on following statements: (true, not true, explain why?)

- a). The equilibrium temperature of Venus is lower than that of Earth, even though Venus is nearer to the sun.
- b) Concentrations of CO<sub>2</sub>, krypton-85, and other gases emitted mainly in the northern hemisphere DECREASE with altitude in the northern hemisphere but INCREASE with altitude in the southern hemisphere.
- c) The presence of a cloud cover tends to favor lower daytime temperatures and higher nighttime temperatures.

**Exercise 3:**

Consider a simplified planet-atmosphere system where a thin atmospheric layer is at some distance from the surface of the planet. The albedo of the planet's surface is  $A$ . The surface perfectly absorbs infrared radiation; i.e. it can be considered a blackbody in this wavelength region. There is no scattering of sunlight in the atmosphere, so the albedo of the atmosphere by itself is 0. The transmissivity of the atmosphere is  $\tau_s$  for sunlight and  $\tau_i$  for infrared radiation. The average incident solar radiation per surface area of the planet is  $Q$ . (For clarification: of the incident radiation  $Q$  the fraction  $\tau_s Q$  is transmitted through the atmosphere, and the fraction  $(1-\tau_s)Q$  is absorbed.)

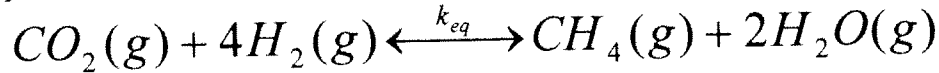
- a) Show that the surface temperature  $T_0$  of the planet is given by following relation:

$$\sigma T_0^4 = Q \left[ \frac{1 + \tau_s}{1 + \tau_i} \right] (1 - \tau_s A)$$

- b) Using the relation above show that for some choices of  $\tau_s$ ,  $\tau_i$ , and  $A$  the surface temperature is lower than the equilibrium temperature  $T_E$  of the planet. (This would be a sort of negative greenhouse effect).

**Exercise 4:**

It has been suggested that hydrogen in the Earth's primitive atmosphere led to the production of CH<sub>4</sub> by the reaction



- a) The equilibrium constants  $k_{eq}$  for this reaction at 300 and 400 K are  $5.2 \times 10^{19}$  and  $2.7 \times 10^{12} \text{ bar}^{-2}$ , respectively. If the partial pressures of H<sub>2</sub>O, CO<sub>2</sub>, and H<sub>2</sub> in the primitive atmosphere were taken to be  $3.0 \times 10^{-2}$ ,  $3 \times 10^{-4}$ , and  $5.0 \times 10^{-5}$  bar, respectively, what are the equilibrium pressures of CH<sub>4</sub> at 300 and 400 K?
- b) The equilibrium constants  $k_{eq} = k_{forward}/k_{backward}$ . At 400 K  $k_{forward}$  is large, but at 300 K it is immeasurably small. Is it likely that this reaction was responsible for the conversion of much H<sub>2</sub> into CH<sub>4</sub> in the primitive atmosphere? Why, or why not?

**Exercise 5:**

In the year 2000 a total amount of  $3.0 \times 10^{13}$  kg of fossil fuels has been burned. Assuming that 50% of the emitted CO<sub>2</sub> accumulates in the atmosphere, what is the averaged increase of the CO<sub>2</sub> mixing ratio (in ppm) in the atmosphere? Assume that 80% of the weight of fossil fuels is carbon; the molecular weights of C, O, and air are 12, 16, and 29 g/mol respectively. (Mass of atmosphere:  $5.2 \times 10^{18}$  kg)

**Exercise 6 (please on a separate sheet!):**

- a) Leg kwalitatief uit wat voor stralingsforcering ontstaat aan het aardoppervlak, in de atmosfeer en aan de top van de atmosfeer als gevolg van aerosol dat zowel zonlicht terugkaatst als absorbeert.
- b) Leg kort uit hoe de aanwezigheid van roet in de atmosfeer het regionale klimaat kan veranderen. Denk hierbij ook aan neerslag.
- c) Beschouw een wolk met een dikte van 200 m, een wolkendruppelconcentratie van  $75 \text{ cm}^{-3}$  en een druppelstraal van  $12.5 \text{ }\mu\text{m}$ . Bereken het albedo  $A$ , met  $A = \tau / (\tau + 6.7)$  en  $\tau$  de optische dikte.
- d) Nu heeft de wolk uit c) een druppelconcentratie van  $225 \text{ cm}^{-3}$ . Bereken de forcering  $\Delta F$  ten opzichte van de wolk uit c). De zonneconstante  $S$  is  $1360 \text{ W m}^{-2}$ .