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In 2005/2006, the course NS-255b was given by dr. G.J.H. Roelofs.

Klimaatfysica en chemie (NS-255b) 2006[1]

Question 1

Explain the following:

a) The percentage of the total oxygen in the atmosphere that is in the form of atomic oxygen increases rapidly with increasing altitudes above $\sim$ 80 km, and above $\sim$ 180 km almost all of the oxygen is atomic oxygen.

b) Why do objects viewed in direct sunlight, particularly around sunrise and sunset have a reddish color?

c) Pressure in the atmosphere increases approximately exponentially with depth, whereas the pressure in the ocean increases approximately linearly with depth.

d) The presence of a cloud cover tends to favor lower daytime temperatures and higher nighttime temperatures.

Question 2

It has been suggested that hydrogen in the Earth's primitive atmosphere led to the production of CH_4 by the reaction

$$\mathrm{CO_2}\ (\mathrm{g}) + 4\mathrm{H_2}(g) \underset{k_{\text{forward}}}{\overset{k_{\text{backward}}}{\rightleftharpoons}} \mathrm{CH_4}\ (\mathrm{g}) + 2\ \mathrm{H_2O}\ (\mathrm{g})$$

a) The equilibrium constants k_{eq} for this reaction at 300 and 400 K are 5.2×10^{19} and 2.7×10^{12} bar^{-2}, respectively. If the partial pressures of H_2O, CO_2, and H_2 in the primitive atmosphere were taken to be 3.0×10^{-2}, 3×10^{-4}, and 5.0×10^{-5} bar, respectively, what are the equilibrium pressures of CH_4 at 300 and 400 K?

b) Remember that the equilibrium constants $k_{\text{eq}} = \frac{k_{\text{forward}}}{k_{\text{backward}}}$. At 400 K k_{forward} is large, but at 300 K it is immeasurably small. It is likely that this reaction is responsible for the conversion of much H_2 into CH_4 in the primitive atmosphere? Why, or why not?

Question 3

If a woman lives to an age of 78 years, what percentage of the particular O_2 molecules that were in the atmosphere when she was born will be there when she dies? (Assume a residence time for O_2 in the atmosphere of 5000 years.

Question 4

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

[1] De exacte datum van dit tentamen is helaas onbekend.

is no scattering of sunlight in the atmosphere, so the albedo of the atmosphere itself is 0. The transmissivity of the atmosphere is τ_{s} for sunlight and τ_{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 $\tau_{\mathrm{s}}Q$ is transmitted through the atmosphere, and the fraction $(1-\tau_{\mathrm{s}})Q$ is absorbed.)

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

$$\sigma T_0^4 = Q\left[\frac{1+\tau_{\mathrm{s}}}{1+\tau_{\mathrm{i}}}\right](1-\tau_{\mathrm{s}}A)$$

b) Using the relation above, show that for some choices of τ_{s}, τ_{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).

Question 5

If air contains water vapour with a mixing ratio of 5.5 g/kg and the total pressure is 1026.8 mbar, calculate the total water vapour pressure. (Molecular weight of water is 18 g/mol; air 29 g/mol.)

Question 6

The total optical depth of the atmosphere is 0.4 for visible sunlight. How much is the solar radiation reduced for a zenith angle of

a) $0°$?

b) $60°$?

Question 7

In the year 2000 a total amount of 3.0×10^{13} kg of fossil fuels has been burned. Assuming that 50% of the emitted CO_2 accumulates in the atmosphere, what is the averaged increase of the CO_2 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 are air 12, 16 and 29 g/mol respectively.