Birla Institute of Technology & Science, Pilani, Rajasthan - 333 031

II Semester, 2021-2022

CHEM F430 Atmospheric Chemistry

Mid-Sem **Time: 90 mins.** **Date: 14.03.2022** **[60 M]**

Useful information: ρ_{H2O} = 1000 kg/m^3; Radius of earth = 6400 km; $P_{surface}$ = 1000 hPa; $P_{tropopause}$ = 150 hPa; $P_{stratopause}$ = 1 hPa; Density of air = 2.5×10^{19} molecules/cm^3; $K_z = 1 \times 10^5$ cm^2 s^{-1}; 1 amu = 1.66054×10^{-27} kg; h = 6.626×10^{-34} J s; 1 Tg = 1×10^{12} g; R = 8.314 J K^{-1} mol^{-1}; Γ = 9.8 K km^{-1};

Q1. (a) The mass percentage of dry air at the sea level is approximately N_2: 75.52 ; O_2: 23.15; Ar: 1.28; and CO_2: 0.046. What is the partial pressure of each component (in atm.)? Total pressure is 1.00 atm. **[5]**

(b) On mars, the atmosphere is mainly composed of CO_2. The average temperature is 220 K and acceleration due to gravity is 3.7 m/s^2. Consider an elementary slab of Martian atmosphere of thickness dZ and horizontal area A at an altitude Z. Derive an expression for the dependence of pressure (P) on altitude (Z). Determine the value of scale height in Martian atmosphere. Compare the scale height of Martian atmosphere and Earth's atmosphere in brief (1-2 lines only). **[7]**

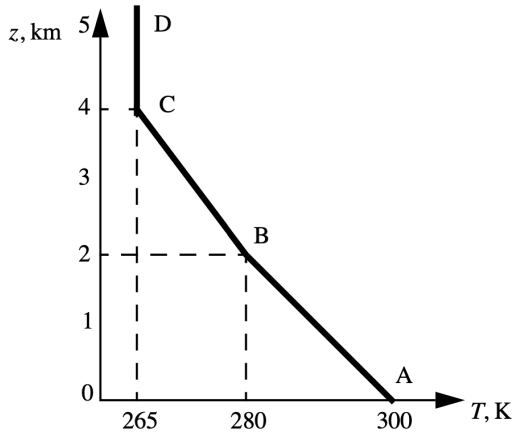
Q2. (a) Water is supplied to the atmosphere by evaporation from the surface and removed by precipitation. The total mass of water in the atmosphere is 1.3×10^{16} kg and global mean rate of precipitation to the Earth's surface is 0.2 cm/day. Calculate the residence time of water in atmosphere. **[4]**

(b) (i) Assume m'_T and m'_S represent the total mass of air in the troposphere and stratosphere, respectively. Residence time of air in stratosphere (τ_S) = 1.3 years. The residence time of air in troposphere is $\tau_T = \tau_S \left(\frac{m'_T}{m'_S}\right)$. Determine the residence time of air in the troposphere (in years). **[3]**

(ii) Hydrochlorofluorocarbons (HCFCs) have been adopted as replacement product for the chlorofluorocarbons (CFCs), which were banned by the Montreal protocol because of their harmful effect on the ozone layer. In contrast to the CFCs, the HCFCs can be oxidized in the troposphere, and the oxidation products washed out by precipitation, so that most of the HCFCs do not penetrate into the stratosphere to destroy ozone. Two common HCFCs have trade names HCFC-123 and HCFC-124; their life-time against oxidation in the troposphere are 1.4 years and 5.9 years, respectively. There are no other sinks for these species in the troposphere. Using two-box model, determine what fractions of the emitted HCFC-123 and HCFC-124 penetrate to the stratosphere. **[5]**

Q3. (a) Energy is released due to cloud formation. Explain this observation at the molecular level. **[2]**

(b) Consider the vertical temperature profile shown in the following Figure. Identify stable and unstable regions (AB, BC, and CD) in the profile with a brief explanation. **[5]**

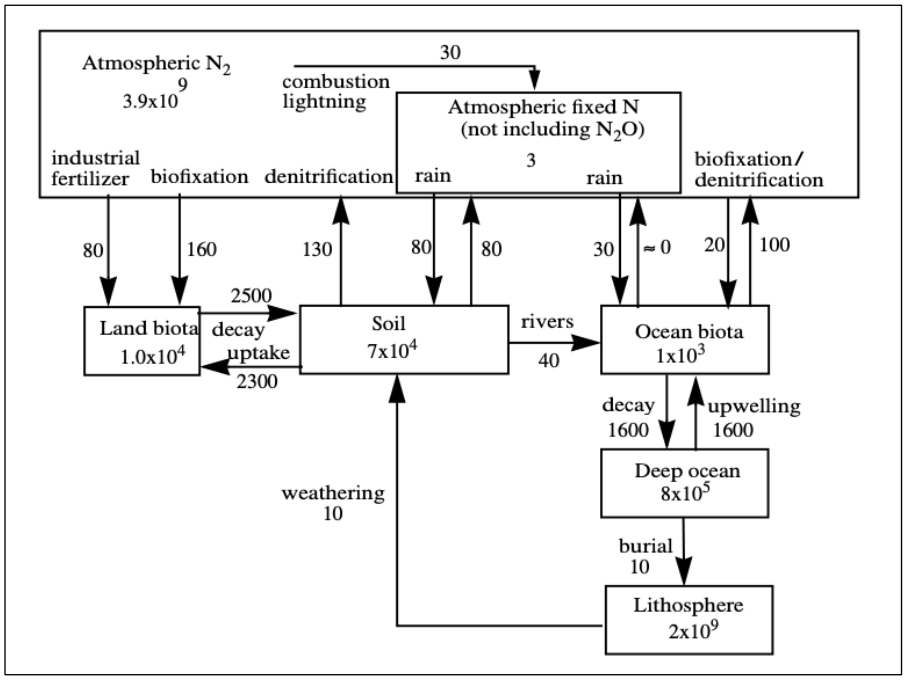


(c) We wish to determine the emission flux of isoprene from a forest canopy. Measurement from a tower above the canopy indicate mean isoprene concentration of 1.5 ppbv at 20 m altitude and 1.2 ppbv at 30 m altitude. Calculate the emission flux of isoprene. **[5]**

Q4. (a) Consider the propagation of radiation of wavelength λ in atmosphere through a layer of thickness dx and perpendicular to a beam of intensity $F(\lambda)$. Derive an expression for Beer-Lambert law. **[3]**
(b) Solar radiation spectra measured from a satellite outside the Earth's atmosphere and at the sea level are different. Explain in brief with examples. **[3]**

(c) Estimate the maximum wavelength of light (in nm) at which the photodissociation of O_2 into two ground state oxygen atoms occurs. $O_2 + h\nu \rightarrow O + O$, ΔH = 498.4 kJ/mol. Calculate atmospheric transmittance as a result of absorption by O_2. Comment whether O_2 is optically thick or thin based on your result. You may use the following information: $\sigma_{max}(O_2) \approx 10^{-17}$, $\tau_{O2} \approx 4 \times 10^7$. **[6]**

Q5. (a) Evaluate the rotational constant of $^1H^{35}Cl$ molecule in Hz. Equilibrium bond length of $^1H^{35}Cl$ molecule is 127.4 pm. **[3]**
(b) Determine the turbulent transport flux of a pollutant X that is well mixed in the atmosphere. **[2]**
(c)



The above Figure represents Box-model of the nitrogen cycle. Inventories are in Tg N and flows are in Tg N yr^{-1}. Calculate the residence time (in years) of nitrogen in each of the reservoirs. **[7]**

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