CVL313: Air and Noise Pollution
Minor 2: Model Answer

Date 24-03-2018

Time: 1 hour **Total marks:20**

NOTE: All answers should be written on answer sheet only. Nothing should be written on the question paper, calculator exchange is not allowed.

1. Brief the fate of sulfur containing compounds in the atmosphere. List two examples each in of gas and aqueous phase sulfur compounds.

Sulfur occurs in five oxidation states in the atmosphere. The chemical reactivity of atmospheric sulfur compounds is inversely related to their sulfur oxidation state. Reduced sulfur compounds with oxidation sate -2 or -1 are rapidly oxidized by OH radicals. The water solubility of sulfur species increases with oxidation state; reduced sulfur species occurs preferentially in gas phase whereas the S(+6) compounds often tend to be found in particle or droplet phase.

Example

Gas phase: Hydrogen sulfide (H_2S), Dimethyl sulfide (CH_3SCH_3)

Aqueous: Bisulfite ions (HSO_3-) and Sulfuric acid (H_2SO_4)

2. Write the equations concerning formation of ozone in the troposphere through chemical reaction with CO and NO_2. What is Dobson unit?

$$CO + OH \rightarrow CO_2 + H \ldots\ldots (1)$$
$$H + O_2 + M \rightarrow HO_2 + M \ldots\ldots (2)$$
$$HO_2 + NO \rightarrow NO_2 + OH \ldots\ldots (3)$$
$$NO_2 + h\nu \rightarrow NO + O \ldots\ldots (4)$$
$$O_2 + O + M \rightarrow O_3 + M \ldots\ldots (5)$$

Dobson unit: The thickness of the O_3 layer measured near earth's surface (273 K, 1 atm) in hundredths of a mm is called column abundance of O_3 in Dobson unit.

3. What is the column burden of O_3 with respect to 3 DU? Write the expression.

Column burden of O_3 corresponding to 3 DU

$$h = \frac{\bar{n}_{o_3} \times R \times T}{p} \times 10^6$$
$$0.003 = \frac{\bar{n}_{o_3} \times 8.314 \times (273 + 25)}{(1.013 \times 10^5)\,(6.023 \times 10^{23})} \times 10^6\ (cm)$$
$$R = 8.314$$
$$T = 273 + 25 = 298\ K \text{ OR T=273 K}$$
$$\bar{n}_{o_3} = 7.39 \times 10^{16}\ molecule\ cm^{-2} \text{ OR } 8.064 \times 10^{16} molecule\ cm^{-2}$$

4. The emitted amount of sulfur containing compounds is 143 Tgy^{-1}. The global mean mixing ratio in 2011 of sulfur containing compounds was 324 ppb. On the basis of these two values estimate the mean life time of sulfur containing compounds in the atmosphere.

Mass of the troposphere is $4 \times 10^{21} g$. Total mass of sulfur containing compounds in the troposphere $324 \times 10^{-9} \times 4 \times 10^{21} = 1.296 \times 10^{15} g$

$$\tau = \frac{Q}{P\ Or\ R} = \frac{1.296\ \times 10^3\ Tg}{143\ Tgy^{-1}} = 9\ years$$

5. Explain the formation of OH radical in the atmosphere using chemical reactions
In troposphere the OH radical is produced through following reactions. OH radical forms through O_2, O_3 and H_2O. OH radical is unreactive towards O2 therefore it survives to react with virtually all atmospheric trace species.
O3 photolysis at <319 nm.
$O_3 + h\nu \rightarrow\ O_2 + O\ (Gound\ state\ O)$----(1a)
$O_3 + h\nu \rightarrow\ O_2 + O(\ ^1D)\ (excited\ singlet\ O(\ ^1D)$----(1b)

$O + O_2 + M \rightarrow\ O_3 + M$----(2)

1a followed by 2 has no net chemical effect (Null cycle)

$O(\ ^1D) + M \rightarrow\ O + M$----(3) [M could be N_2 or O_2, most often this reaction happens]

$O(\ ^1D) + H_2O \rightarrow\ 2OH$----(4)

Again reaction 1b followed by 3 and 2is just another null cycle.
Reaction 4 is only reaction in the atmosphere able to break the H-O bond in H_2O.

6. Define nucleation and accumulation mode particles. Comment of their formation, composition, life time, removal process and distance travel.

	Nucleation mode	Accumulation mode
Formed from	Combustion, high temperature processes and atmospheric reaction	
Formed by	Nucleation, condensation, coagulation	Condensation, coagulation, evaporation of fog and cloud droplets in which gases have dissolved and reacted
Composed of	Sulfates, elemental carbon, metal compounds, organic compounds with very low saturation vapor pressure at ambient temperature	SO42-, NO3-, NH4+, H+, EC, organic compounds, metal compounds of Pb, Cd, V, Ni, Cu, Zn, Mn, Fe etc.
		Particle bound water
Atmospheric half-life	Minutes to hours	Days to week
Removal process	Grows into accumulation mode	Forms cloud droplets and rains out
Travel distance	<1 to 10s of km	100s to 1000s of km

7. List the aerosol sources in descending order
   Natural primary>Anthropogenic Secondary>Anthropogenic primary>precursor of natural secondary aerosol

8. In 1991 a volcano mount Pinatubo exploded, injecting dust 32 km up into the atmosphere. Fallout from this explosion continued for 15 months. If one assumes that the velocity of particles was constant and neglects the slip correction, what was the minimum particle size present? Assume that the particles are rock sphere with a density of 2700 kg/m^3.

$$v = \frac{32 * 1000}{15 * 30 * 24 * 60 * 60} = 8.23 \times 10^{-4}$$

$$v_{ts} = 8.23 \times 10^{-4} = \frac{\rho_p \times d^2 \times g}{18 \times \eta} = \frac{2700 \times (d^2) \times 9.81}{18 \times 1.81 \times 10^{-5}}$$

$$d = 3.18 \times 10^{-6}\, m = 3.2\, \mu m$$