

1. Ozone is an important chemical species in the atmosphere. It plays different roles over stratosphere and troposphere, respectively.

(a) (9 pts) Please describe in detail about the impact of ozone to human and the environment for the following environments; (i) ozone at surface layer, (ii) ozone at upper troposphere and (iii) ozone at stratosphere.

(b) (12 pts) The ozone formation over the stratosphere is based on the Chapman mechanism with four major reactions. Please describe these four reactions.

(c) (12 pts) Figure 1-1 shows the temporal profile for several given parameters related to the formation of ozone hole. With all information provided in Figure 1-1, please describe in detail how the ozone hole happens (please include the following information: when, where, what reaction causes the ozone hole as compared with other regions).

(d) The dependence of ozone production on NO_x and hydrocarbons (RH) in the troposphere can be summarized into a flow chart as shown in Figure 1-2. OH, RO, RO₂ and HO₂ are in HO_x family. P_{HO_x} is the HO_x production rate while k₄, k₅, k₆, k₇, k₈ and k₉ are the rate constants for the reactions shown in Figure 1-2.

(i) (5 pts) Please describe in detail how OH is produced in the troposphere through the photolysis of O₃.

(ii) (6 pts) Please describe in detail how the O₃ is produced through reactions 5 and 7, respectively.

(iii) (16 pts) At high NO_x condition, HO_x is removed through reaction 9 while at low NO_x condition, HO_x is removed through reaction 8. Because reactions of 4, 5, 6 and 7 are so fast as compared to other reactions in Figure 1-2, the reaction rates of 4, 5, 6 and 7 are the same. With this statement, please derive the ozone production rates (P_{O₃}) for the following conditions:

$$P_{O_3} = 2k_7 \left(\frac{P_{HO_x}}{2k_8} \right)^2 [NO] \text{ at low NO}_x \text{ condition; and}$$

$$P_{O_3} = \frac{2k_4 P_{HO_x} [RH]}{k_9 [NO_2][M]} \text{ at high NO}_x \text{ condition.}$$

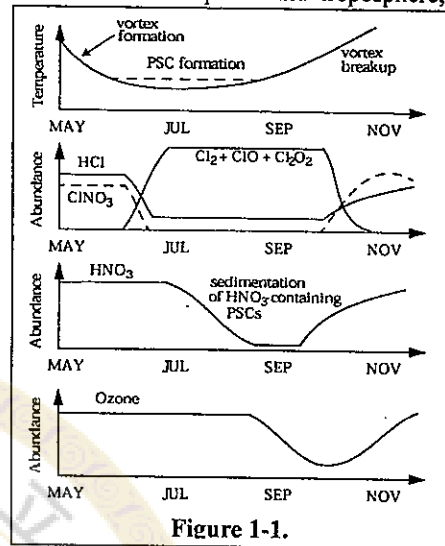


Figure 1-1.

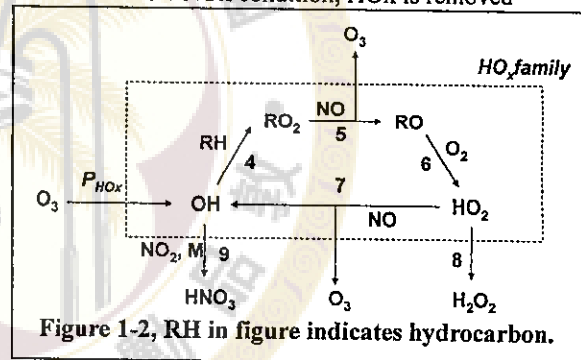


Figure 1-2, RH in figure indicates hydrocarbon.

(iv) (10 pts) Based on (iii), the ozone concentration (ppbv) simulated by a regional photochemical model as a function of NO_x and hydrocarbon emissions is shown in Figure 1-3. The thick line separates the plot into A and B regimes. With the air pollution control, the concentrations of CO and NO_x in most observation sites of Taiwan are getting lower but the ozone concentration is getting higher. Please explain the observed result of Taiwan observation sites with all possibility based on (iii) and Figure 1-3.

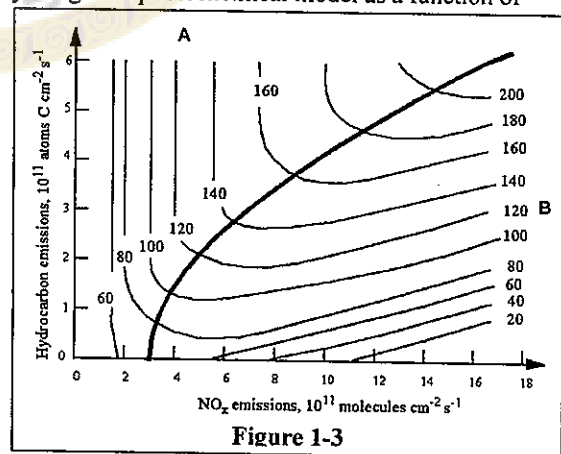


Figure 1-3

2. Aerosol particles can affect the radiation budget of the Earth via direct and indirect effects.

(a) (10 pts) Please describe all sources of aerosol particles including the formation mechanism for primary and secondary aerosol particles.

(b) (10 pts) Please describe in detail the direct effect of aerosol particles on the radiation budget including warming and cooling effects.

(c) (10 pts) Please describe in detail the indirect effect of aerosol particles through cloud on the radiation budget including how the aerosol particles modify the cloud formation.