Review Questions

1. What is a *Dobson Unit*? How is it used in relation to atmospheric ozone levels?

2. If the overhead ozone concentration at a point above the Earth's surface is 250 DU, what is the equivalent thickness in millimeters of pure ozone at 1.0 atm pressure?

3. Describe the process by which chlorine becomes activated in the Antarctic ozone-hole phenomenon.

4. What are the steps in Mechanism II by which atomic chlorine destroys ozone in the spring over Antarctica?

5. Describe the reasons why the Antarctic ozone hole closes in late spring/early summer.

6. Explain why full-scale ozone holes have not yet been observed over the Arctic.

7. What are two effects to human health that scientists believe will result from ozone depletion?

8. Define what is meant by a tropospheric *sink*.

9. Explain what *CFCs* were and some of their uses. Did they have a tropospheric sink? Why did their emissions in air lead to an increase in stratospheric chlorine?

10. Explain what *HCFCs* are and state what sort of reaction provides a tropospheric sink for them. Is their destruction in the troposphere 100% complete? Why are HCFCs not considered to be suitable long-term replacements for CFCs?

11. What types of chemicals are proposed as long-term replacements for CFCs?

12. Chemically, what are *halons*? What was their main use?

13. What gases are being phased out according to the Montreal Protocol agreements?

Additional Problems

1. (a) Some authors use milliatmospheres centimeter (matm cm) rather than the equivalent Dobson Unit to express the unit for the amount of overhead ozone; 1 matm cm = 1 DU. Prove that the number of moles of overhead ozone over a unit area on the Earth's surface is proportional to the height of the layer, as specified in the definition of Dobson Units, and that 1 DU is equal to 1 matm cm.

(b) Calculate the total mass of ozone that is present in the atmosphere if the average overhead amount is 350 Dobson Units, and given that the radius of the Earth is about 6400 km. [Hints: The volume of a sphere, which you can approximate the Earth to be, is $4\pi r^3/3$. You may assume that ozone behaves as an ideal gas.]

2. The chemical formula for any CFC, HCFC, or HFC can be obtained by adding 90 to its code number. The three numerals in the result represent the number of C, H, and F atoms, respectively. The number of Cl atoms can then be determined using the condition that the number of H, F, and Cl atoms must add up to $2n + 2$, where n is the number of C atoms. From this information, deduce the formulas for compounds with the following codes:

(a) 12 (b) 113 (c) 123 (d) 124

3. Using the information discussed in Problem 2 above, deduce the code numbers for each of the following compounds:

(a) CH_3CCl_3 (b) CCl_4 (c) CH_3CFCl_2

4. Using the information in Problem 2, show that 134 is the appropriate label for CH_2FCF_3. Why is an a or b designation also required to uniquely characterize the latter compound? What would be the code numbers for the HCFs in R-410a, namely CH_2F_2 and CHF_2CF_3? Does the number 410 correspond to the code number for either of these compounds?

5. The chlorine dimer mechanism is not implicated in significant ozone destruction in the

lower stratosphere at mid-latitudes even when the particle concentration becomes enhanced by volcanoes. Deduce two reasons why this mechanism is not important under these conditions.

6. When Mechanism II for ozone destruction operates with X = Cl and X′ = Br, the radicals ClO and BrO react together to reform atomic chlorine and bromine (see Problem 2-1). A fraction of the latter process proceeds by the intermediate formation of BrCl, which undergoes photolysis in daylight. At night, however, all the bromine eventually ends up as BrCl, which does not decompose and restart the mechanism until dawn. Deduce why all the bromine exists as BrCl at night, even though only a fraction of the ClO with BrO collisions yields this product.

7. Explain what changes are observed in the UV-B intensity at ground level during ozone hole episodes.

8. What would be the advantages of using hydrocarbons rather than HFCs or HCFCs as aerosol propellant to replace CFCs? What is their major disadvantage? What type of agent should be added to aerosol cans containing hydrocarbon propellants to overcome this disadvantage and make them safer?

9. Consider the following set of compounds: $CFCl_3$, $CHFCl_2$, CF_3Cl, and CHF_3. Assuming that equal numbers of moles of each were released into the air at ground level, rank these four compounds in terms of their potential to catalytically destroy ozone in the stratosphere. Explain your ranking.