

**CHEM. 250 – Spring, 2015**  
**Exam 1**

Name \_\_\_\_\_

**Short Answer and Multiple Choice Section. For multiple choice problems, select the best (only one) answer. 4 points per problem.**

Answer the following two questions using the 4 **stratospheric** Chapman mechanism reactions:

- a)  $O_2 + h\nu \rightarrow 2O$
- b)  $O + O_2 + M \rightarrow O_3 + M$
- c)  $O_3 + h\nu \rightarrow O_2 + O$
- d)  $O + O_3 \rightarrow 2O_2$

1. Which reaction results in removal of harmful UV-C (220 to 280 nm) light and reduction of harmful UV-B (280 to 320 nm) light reaching the earth's surface? \_\_\_\_
  
2. Catalysis of which reaction through mechanism I (with Cl, NO, or OH) leads to loss of ozone \_\_\_\_\_
  
3. Which of the following conditions is a significant factor in the production of a stratospheric ozone hole?
  - a) the presence of polar stratospheric clouds
  - b) the removal of  $NO_x$  from the gas phase
  - c) the reactivation of Cl once the sun becomes present
  - d) all of the above
  
4. In the lower altitude polar stratosphere, in which way is chlorine most responsible for ozone destruction?
  - a) ozone destruction through a mechanism I type reaction
  - b) ozone destruction through a mechanism II type reaction (dimer forming intermediate)
  - c) activation of  $NO_x$  catalyzed ozone destruction
  - d) activation of  $HO_x$  catalyzed ozone destruction
  
5. Which compound initiates oxidation of alkanes in the **troposphere**?
  - a) OH
  - b)  $HO_2$
  - c)  $NO_2$
  - d)  $O_3$
  
6. Which of the following is the most significant source of NO in the **troposphere**?
  - a) oxidation of  $N_2O$
  - b) fuel N in the combustion of coal
  - c) thermal NO from high temperature fuel combustion
  - d) oxidation of  $NH_3$
  
7. Which of the following is a significant primary pollutant?
  - a) CO
  - b)  $O_3$
  - c)  $HNO_3$
  - d)  $H_2SO_4$

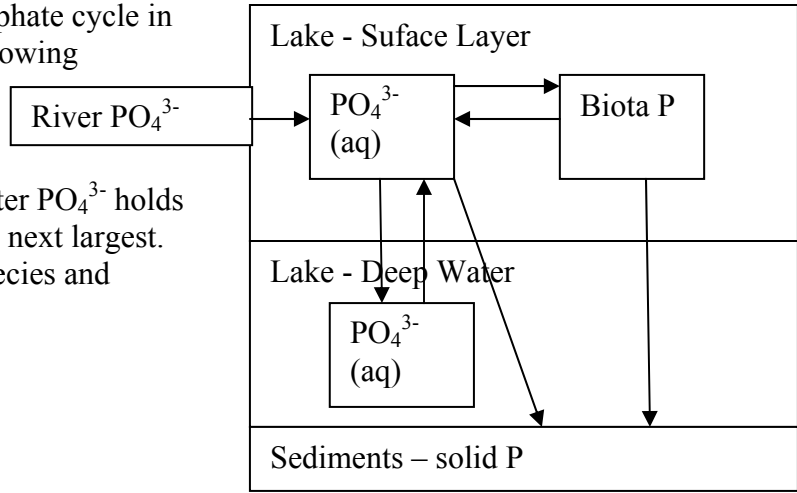
8. The midwestern region of the US has higher sources of acid precursors ( $\text{SO}_2$  and  $\text{NO}_x$ ) than the northeastern region of the US. However, the northeastern region has seen more damage to its watersheds. Give one possible explanation for why this is:

---

9. List one type of meteorological condition which contributes to photochemical smog episodes. Conditions: \_\_\_\_\_

**Problem and Short Essay Question Section (be sure to show work if calculations are needed):**

1. Using the diagram of the phosphate cycle in a lake to the right, answer the following questions.



a) In this particular lake, deep water  $\text{PO}_4^{3-}$  holds the most P, with biota P being the next largest. Which species is a “reservoir” species and which is “flux” species? (6 pts)

b) Biota P sinks to the bottom when the biota dies, which is the main P sink in the lake. If the average lifetime of the biota is 6 months, the lake biomass is  $3.8 \times 10^4$  kg, and the %P of the biomass is about 0.5%, **calculate the biota P sink flux to sediments** in kg P/year. Assume the average lifetime is the turnover time. (8 pts)

2. If the formation of reservoir species is ignored,  $\text{NO}_x$  can act as a catalyst for ozone destruction in the stratosphere by a mechanism I reaction. Write out the two reaction steps showing ozone destruction? (6 pts)

bonus – from 2) Write one reaction which reduces  $\text{NO}_x$ 's effectiveness in destroying ozone. This could be a reaction producing ozone or forming an inactive species. (3 pts)

3. Give one Cl containing reservoir species that reactivates during ozone hole chemistry and explain (words or reactions) how Cl is reactivated. (8 pts)

4. Describe  $\text{NO}_x$ 's role in the production of tropospheric ozone by:

a) giving a two step reaction of an  $\text{NO}_x$  species forming ozone (6 pts) and

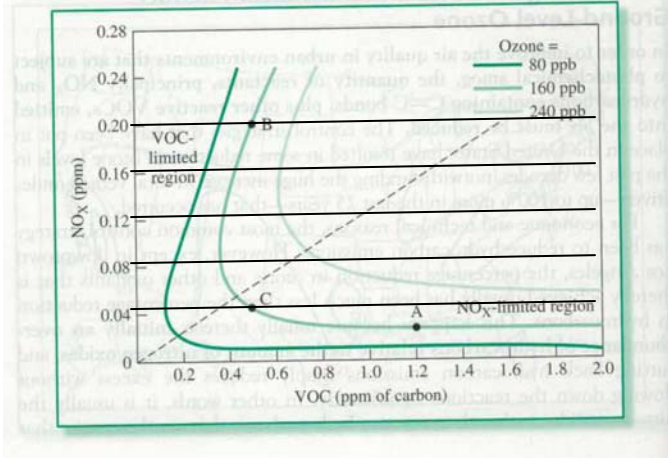
b) giving another reaction by which the  $\text{NO}_x$  product of the reaction in a) is recycled back to the  $\text{NO}_x$  reactant in step a) (without also destroying ozone). (4 pts)

5. One way in which sulfuric acid is formed in the atmosphere is through gas phase reaction with OH.

a) Describe how this sulfuric acid ends up atmospheric aerosol particles and to what sized particles they add to the mass? (6 pts)

b) Does the size of the particles the sulfate ends up on affect the amount of haze? If so, what size causes the greatest decrease in visibility (per g of sulfate formed). (6 pts)

5. In an urban area in the Southeastern US, the total VOC (hydrocarbon) concentration is found to be 0.8 ppm C (1/2 anthropogenic and 1/2 natural) with  $\text{NO}_x$  concentrations of 0.16 ppm. Use the plot below to answer the following questions.



a) Based on the plot, which source should be reduced. Explain your answer. (4 pts)

b) The pollution plume drifts downwind and can be assumed to be diluted by a factor of 8 by background air (which has no  $\text{NO}_x$  but the same level of natural VOCs), show the new conditions on the plot. Is the limiting reactant the same or different? Explain your answer. (7 pts)

7. Determine the pH and aqueous  $\text{NO}_3^-$  concentration (in M) if air containing 1.0 ppbv  $\text{HNO}_3$  enters a cloud with a pressure of 0.90 atm, a T of 293K, and a liquid water content (LWC) of  $0.50 \text{ g H}_2\text{O} (\text{m air})^{-3}$ . Assume that 100% of the  $\text{HNO}_3$  is scavenged and  $\text{HNO}_3$  behaves as a strong acid. The density of water is  $1.0 \text{ g mL}^{-1}$ . (12 pts)  
 $R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$ .  $1000 \text{ L} = 1 \text{ m}^3$ .