CHEM173 Midterm 1 **Name**_____
Spring 2006 UCSD ID Number_____

1. Greenhouse Gases (50 pts: 10, 10, 10, 10, 10)
a) What is a greenhouse gas? Also, name two examples.

A greenhouse gas is a molecule in the atmosphere that absorbs infrared radiation re-emits it back to heat the Earth's surface. Examples: H_2O, CO_2.

b) If there were no greenhouse gases in the atmosphere, what would be the approximate global mean surface temperature of the Earth? State your assumptions.

If we assume the Earth acts as a blackbody, the atmosphere is in radiative equilibrium, the albedo reflects 31% of incoming solar radiation, and the atmosphere is transparent to incoming solar radiation, then the global mean surface temperature is given by:

$F_S = F_L$

$0.25*S_0(1- \alpha_p) = sT_e^4$

$T_e = [0.25*S_0(1- \alpha_p)/s]^{0.25} \sim 255K$

c) What is the observed global mean surface temperature of the Earth?

The observed global mean surface temperature is 288K.

d) What is the role of greenhouse gases in accounting for the difference between the observed temperature in (c) and the temperature of the Earth that you estimated in (b)?

Greenhouse gases absorb infrared radiation emitted by the Earth, and re-emit it to warm the Earth's surface by more than 30K compared to the calculation in (b) without an atmosphere.

e) Give an example of an *anthropogenic* greenhouse gas. What impact would you expect from the observed increases of *anthropogenic* greenhouse gases on the global mean temperature of the Earth?

CO_2 is an example of an anthropogenic greenhouse gas. The observed increases in concentration of CO_2 will cause the global mean temperature of the Earth to increase.

2. Chapman Cycle (50 pts: 10, 20, 10, 10)
a) What is the Chapman cycle?

The Chapman cycle describes the four steps by which O_2 is photolyzed to produce O atoms and O_3, which can then be photolyzed to recover O_2.

b) Write the four reactions for the Chapman cycle.

$O_2+h\nu \rightarrow O+O$

$O+O_2+M \rightarrow O_3+M$

$O_3+h\nu \rightarrow O_2+O$

$O+O_3 \rightarrow O_2+O_2$

c) What feature in the atmosphere results from the Chapman cycle? Name the part of the atmosphere in which this feature located.

The ozone layer is formed by the Chapman cycle. The ozone layer is located in the stratosphere.

d) What chemical component has concentrations of up to 5-10 ppmv in this part of the atmosphere?

Ozone has a concentration of up to 5-10 ppmv in the stratosphere.

3. Ozone Hole (60 pts: 10, 10, 10, 10, 20)

a) What is the ozone hole?

The ozone hole describes the depletion of the stratospheric ozone layer at the Arctic and Antarctic poles.

b) Describe the five steps required for the formation of the ozone hole.

1. Polar vortex transports HCl, ClO and $ClONO_3$ produced by photolysis at 25km.
2. Stratospheric ice (<-80°C) forms PSCs.
3. HCl and $ClONO_3$ make Cl_2 on PSC particles.
4. Cl_2 + sunlight makes Cl.
5. Cl, ClO catalyzes O_3 destruction to O_2.

c) Write the *generalized* mechanism responsible for destruction of ozone by a catalyst "X". Name two catalysts that destroy ozone by this mechanism in the stratosphere.

$XO + O \rightarrow X + O_2$

$X + O_3 \rightarrow XO + O_2$ Net: $O + O_3 \rightarrow 2O_2$

d) What class of *anthropogenic* compounds contribute to the ozone hole? Give an example.

Chlorofluorocarbons (CFCs).

e) State the net reaction for the cycle below. What role does it play in the ozone hole?

$$ClO + ClO + M \xrightarrow{k_1} (ClO)_2 + M$$

$$(ClO)_2 + h\nu \xrightarrow{k_2} Cl + ClOO$$

$$ClOO + M \xrightarrow{k_3} Cl + O_2$$

$$2Cl + 2O_3 \xrightarrow{k_4} 2ClO + 2O_2$$

Net: $2O_3 \rightarrow 3O_2$, destroying ~75% of O_3 lost in the ozone hole.

Assuming that the concentrations of Cl, ClOO, and $(ClO)_2$ are in steady state, write an expression for the concentration of Cl in terms of the concentrations of ClO, O_3, and M and the constants k_1 and k_4.

$[Cl] = (2k_1[M][ClO]^2)/(k_4[O_3])$

4. Composition of the Atmosphere (40 pts: 10, 10, 10, 10)

a) Name the five most abundant components of the atmosphere.

N_2, O_2, Ar, H_2O, CO_2.

b) Give the volumetric percentage of the top two most abundant components.

78% N_2, 21% O_2.

c) Which of the five major components has the most variable composition? Describe the difference in its contribution to the troposphere and stratosphere, and the resulting impact in determining the primary oxidant in each region.

H_2O is the most variable. The stratosphere is very dry and has <1% H_2O. The troposphere has up to 4% H_2O. H_2O in the troposphere results in the formation of OH as the primary oxidant.

d) Name five *kinds* of sources that contribute to the trace components found in the atmosphere. Give two examples of trace components from two of the kinds of sources that you named.

Five kinds of sources of trace atmospheric components are biogenic, anthropogenic, radiogenic, volcanic, and oceanic. Examples: CO_2 is anthropogenic; SO_2 is volcanic.