

Purdue University – Department of Chemical Engineering

Final Examination CHE 348
Closed book and notes

Name: _____
Friday, May 2, 2008

Solutions

1. (15 points) Decomposition of ozone catalyzed by atomic chlorine

The following two-step cycle is believed to occur for the destruction of ozone by chlorine in the stratosphere:



The overall reaction is $\text{O} + \text{O}_3 \rightarrow 2\text{O}_2$. Note that Cl and ClO are very reactive species and that Cl is regenerated at the end of the cycle (Cl is a catalyst for this reaction).

The reaction constants measured experimentally are:

$$k_1 = 5 \times 10^{-11} \exp(-140/T) \text{ cm}^3 \text{ s}^{-1} \text{ and } k_2 = 1.1 \times 10^{-10} \exp(-220/T) \text{ cm}^3 \text{ s}^{-1}$$

- Using the steady-state approximation and the fact that the number of active centers ($[\text{L}] = [\text{Cl}] + [\text{ClO}]$) is a constant show that the rate of ozone decomposition is $r_c = - (k_1 k_2 [\text{L}] [\text{O}] [\text{O}_3]) / (k_1 [\text{O}_3] + k_2 [\text{O}])$
- Since $[\text{O}] \ll [\text{O}_3]$, simplify the denominator for the expression in a). The non-catalyzed rate of ozone decomposition (r_{nc}) is elementary ($\text{O} + \text{O}_3 \rightarrow 2\text{O}_2$) with $k = 1.9 \times 10^{-11} \exp(-2300/T) \text{ cm}^3 \text{ s}^{-1}$

Calculate the ratio of the catalyzed to the non-catalyzed reaction (r_c/r_{nc}) as a function of temperature using $[\text{L}]/[\text{O}_3] = 10^{-5}$, which is the value measured in the stratosphere. Calculate the ratio r_c/r_{nc} for a temperature in the ozone layer of 200 K. Does that explain why Cl destroys the ozone layer? (remember that Cl is not consumed in the cycle, it catalyzes the reaction indefinitely)

Chemical Reaction Engineering Final Exam Solution

S Ben Porath



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