AP® Chemistry
2002 Sample Student Responses

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Answer EITHER Question 7 below OR Question 8 printed on page 24. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. An environmental concern is the depletion of O_3 in Earth's upper atmosphere, where O_3 is normally in equilibrium with O_2 and O. A proposed mechanism for the depletion of O_3 in the upper atmosphere is shown below.

Step I $\quad O_3 + Cl \rightarrow O_2 + ClO$

Step II $\quad ClO + O \rightarrow Cl + O_2$

(a) Write a balanced equation for the overall reaction represented by Step I and Step II above.

(b) Clearly identify the catalyst in the mechanism above. Justify your answer.

(c) Clearly identify the intermediate in the mechanism above. Justify your answer.

(d) If the rate law for the overall reaction is found to be $rate = k[O_3][Cl]$, determine the following.

(i) The overall order of the reaction

(ii) Appropriate units for the rate constant, k

(iii) The rate-determining step of the reaction, along with justification for your answer

a) $O_3 + Cl + ClO + O \rightarrow O_2 + ClO + Cl + O_2$

$\boxed{O_3 + O \rightarrow 2O_2}$

b) The catalyst is Cl. It is not in the overall equation for the reaction. It is used to form the reactionary intermediate so the reaction can proceed quicker. It exists in the beginning, gets used up, but then dissociates and exists by itself in the end. That is how catalysts work - they do not affect the overall reaction.

c) The reactionary intermediate is ClO. It is the compound that gets made in Step I, but gets used and changed in the beginning of Step II. Intermediates only exist in the middle of the reaction. They are always the links between the steps.

d) i - The overall order is 1+1 or $\boxed{2}$. The order with respect to O_3 is 1 and the order with respect to Cl is 1, so the overall order is 2.

ii - $rate = k[O_3][Cl]$

$\frac{M}{S} = k \cdot M \cdot M$ → $\frac{M}{S} = M^2 \cdot k$ → $\frac{M}{S \cdot M^2} = k$ → $\boxed{k = \frac{1}{S \cdot M}}$

ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

iii- The rate determining step is Step I. The rate law has $[O_3]$ and $[Cl]$ in it, so you have to find the step with O_3 and Cl as reactants. It is always the reactants of the slow step, or rate determining step, that make the rate law.

 7B

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(i) The overall order of the reaction

(ii) Appropriate units for the rate constant, k

(iii) The rate-determining step of the reaction, along with justification for your answer

(a) $O_3 + Cl \rightarrow O_2 + ClO$
$ClO + O \rightarrow Cl + O_2$
$O_3 + O \rightarrow 2O_2$

(b) The catalyst is Cl because it starts up the reaction that depletes O_3.

(c) The intermediate is ClO because it uses the product of the first reaction that became the reactant of the 2nd reaction.

(d) (i) 2 order reaction $k[O_3]^1[Cl]^1$ $1+1=2$

(ii) K units = M^{-1}/S^{-1} $2-1=1$

(iii) The first one because it's the one that allows both [Cl] and $[O_3]$ to be multiplied together. Step II doesn't even have O_3 in the equation.

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(i) The overall order of the reaction

(ii) Appropriate units for the rate constant, k

(iii) The rate-determining step of the reaction, along with justification for your answer

a. $O_3 + O \rightarrow 2O_2$

b. The catalyst is Cl. The O_3 reacts with Cl instead of O, and creates an entirely new set of reactions.

c. The intermediate in the reaction is ClO. It is created in step 1, then quickly used up in step 2.

d. i. The reaction is 1st order.

ii. $K \rightarrow mol^{-1}\ min^{-1}$

iii. The rate determining step is step 1. The rate law rate = $k[O_3][Cl]$ shows that O_3 and Cl, the reactants in step 1, are important in determining the rate.