Kinetics



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#1. A of a chemical reaction is measured as the change in amount of substances over time.							
#2. Reaction rates are affected by four factors: , , , , catalyst and particle size.							
#3. A	#3. A shows the relationship between the concentration of reactant species raised to some power and the rate.						
#4. The grap	#4. The graph of concentration versus time of reacting species is used to determine whether the of a reaction is						
	zeroth, first or order.						
#5. The rate law of a chemical reaction is inferred from the of the collision of particles for an elementary reaction.							
#6.							
#7. A reactio	#7. A reaction illustrates the energy involved in a reaction as it progresses over time.						
#8. A series of steps for a chemical reaction is represented as a							
KEY VOCAB	Reaction Rate	Concentration	First Order	Catalyst	Reaction Mechanisms		
Q	Rate Law	Surface Area	Second Order	Collision Theory	Slow Step		
Chi	Order of Reaction	Temperature	Zeroth Order	Elementary Reaction	Integrated Rate Law		
■ TOPIC 5.1- REACTION RATES •■							
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1. Use the chemical equation and the given scenarios below to complete the table. Place a 🗸 in the box of the correct response.							
$2 N_2 O_5(g) \rightarrow 2 N_2(g) + 5 O_2(g)$ $\Delta H_{rxn} > 0$							

Scenario	Increase in Rate of Reaction	Decrease in Rate of Reaction	Reaction Rate Unchanged
Increase in $[N_2O_5]$			
Increase in pressure			
Use of a catalyst			
Lower the temperature			
Increase the volume of the container			
Decrease the pressure of N ₂ O ₅			
Add inert He gas			

For the same reaction above, it took 80. seconds for 1.00 M of N_2O_5 to decompose to 0.050 M. Calculate the following:

- 2. The rate of the consumption of N_2O_5 ?
- 3. The rate of production of 0_2 ?
- 4. How does the rate of production of O_2 compare to the rate of consumption of N_2O_5 ? Explain.

■ TOPIC 5.2- INTRODUCTION TO RATE LAW

The initial rates of the reaction represented by the equation below were measured for different initial concentrations of BrO(g) and $I_2(g)$.

$$2 BrO(g) + I_2(g) \rightarrow 2 IO(g) + Br_2(g)$$

Experiment	[BrO] (M)	[l ₂] (M)	Rate of Reaction (M/s)
1	0.01	0.01	5.0 x 10 ⁻⁴
2	0.02	0.01	2.0 x 10 ⁻³
3	0.01	0.02	1.0 x 10 ⁻³
4	0.02	0.02	?

- 5. What is the order of the reaction with respect to BrO?
- 6. What is the order of the reaction with respect to I_2 ?
- 7. Write the rate law for this reaction.
- 8. What is the value of the rate constant, k, for this reaction? Include units.

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■ TOPIC 5.2- INTRODUCTION TO RATE LAW (continued) ■

9. What is the rate of the reaction for Experiment 4?

An experiment was conducted to determine the rate law for the reaction $X_2 + Y_2 \rightarrow 2$ XY. The table below shows the data collected. Based on the data in the table, determine the following.

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Experiment	$[X_2]$	$[Y_2]$	Initial Rate of Appearance of XY		
1	1.5 M	1.5 M	5.0 x 10 ² M/s		
2	3.0 M	1.5 M	1.0 x 10 ³ M/s		
3	1.5 M	6.0 M	2.0 x 10 ³ M/s		

10. The rate law for the reaction.

11. The overall order for this reaction.

12. The value of the rate constant, k.

■ TOPIC 5.3- CONCENTRATION CHANGES OVER TIME

A chemist wanted to collect rate law data on the following chemical reaction: $A \rightarrow B + C + D$. The chemist started with 2.0 M of A and allowed it to decompose over time. After collecting and analyzing the data, the following linear graph was created by plotting 1/[A] versus time.

13. What is the order of the reaction with respect to A? Explain.

15. What is the value of the rate constant, k? Include units. Slope of graph = +k.

14. Write the rate law expression.

16. If this experiment were repeated at a higher temperature, what would happen to the value of k? Explain.

Another chemist wanted to study the product, B, from the previous reaction. As he isolated 1.5 M initially of B, he studied the decomposition over time. $B \to A$. Answer the following questions from the graph of ln[B] v. time below.

17. Explain why the order of the reaction is not 2nd order.

19. Write the Rate law for the decomposition of B.

18. What is the value of the rate constant? Include units.

20. How long will it take 1.0 M to decompose to 0.50 M?

■ TOPIC 5.4- ELEMENTARY REACTIONS ■

Each equation is from the elementary step in a chemical reaction. Write the rate laws for each elementary step and then identify the overall order of the step.

21. 2 POBr \rightarrow 2PO + Br₂

22. $Cl_2 + 2 O_3 \rightarrow 2 ClO_3^-$

23. $CH_3CH_2CI \rightarrow CH_3CH_2^+ + CI^-$

24. Of the three elementary steps in the three previous questions, which would you expect to be the slowest? Explain your answer.

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■ TOPIC 5.5- COLLISION MODEL

The rate-determining step for a reaction is $SO_3(g) \rightarrow SO(g) + O_2(g)$. The <u>graph</u> shows the distribution of energies for $SO_3(g)$ molecules at two temperatures. Answer the following questions regarding this reaction.

- 25. Explain the observation that much less product is formed at Temperature 1 than at Temperature 2.
- 26. Identify two factors that affect the success of a chemical reaction.
- 27. Another reaction was conducted in which the partial pressure of $SO_3(g)$ was increased. This increase in partial pressure resulted in more products being formed. Explain this result using Collision Theory.

■ TOPIC 5.6- REACTION ENERGY PROFILE •

$$\text{CH}_3\text{CI} + \text{OH}^- \rightarrow \text{CH}_3\text{OH} + \text{CI}^-$$

Use the labeled energy profile for the reaction given above to identify the letter(s) that represent each of the following:.

- 28. Enthalpy of reaction, $\Delta H_{\text{rxn.}}$
- 29. Activation Energy of the Reaction, E_a
- 30. Activation Energy of the Reverse Reaction, $E_{a, reverse}$
- 31. The letter(s) affected by the use of a catalyst.
- 32. What is the value of ΔH_{rxn} ?
- 33. Is this reaction exothermic or endothermic? Explain.

- 34. What is the value of the E_{σ} of the forward reaction?
- 35. What is the value of the E_a of the reverse reaction?
- 36. Would the reverse of this reaction happen faster or slower than the forward? Explain.

■ TOPIC 5.7- INTRODUCTION TO REACTION MECHANISMS ■

A similar three step experiment was studied for the oxidation of iodide ion by hydrogen peroxide:

$$H_2O_2 + I^- \rightarrow HOI + OH^-$$
 Step 1 (fast)
 $HOI + I^- \rightarrow I_2 + OH^-$ Step 2 (fast)
 $2 OH^- + 2 H_2O^+ \rightarrow 4 H_2O$ Step 3 (slow)

- 37. What is the overall balanced equation?
- 38. Identify all reaction intermediates.
- 39. Referencing the overall reaction for the oxidation of iodide ions, explain why it is not likely that this reaction occurs in one step.

A two-step reaction mechanism is proposed for a chemical reaction, represented below.

- 40. What is the chemical equation for the overall reaction?
- 41. Identify the reaction intermediate in this mechanism.

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■ TOPIC 5.8- REACTION MECHANISM AND RATE LAW

Following is a representation of a proposed mechanism for the reaction involving the reaction of cyclohexane, $C_6H_{12}(g)$ with bromine, $Br_2(g)$.

 $\begin{array}{lll} \text{Step 1:} & \text{Br}_2 {\longrightarrow} \, 2\text{Br} & \text{(slow)} \\ \text{Step 2:} & \text{Br} + \text{C}_6\text{H}_{12} {\longrightarrow} \, \text{HBr} + \text{C}_6\text{H}_{11} & \text{(fast)} \\ \text{Step 3:} & \text{C}_6\text{H}_{11} + \text{Br} {\longrightarrow} \text{C}_6\text{H}_{11}\text{Br} & \text{(fast)} \\ \end{array}$

- 42. What is the overall balanced equation?
- 43. Write a rate law for the reaction that is consistent with the mechanism. Explain how this rate law is consistent.
- 44. Explain the observation that increasing or decreasing the concentration of $C_6H_{12}(g)$ does not affect the rate of the reaction.
- 45. A student claims that $Br_2(q)$ is a catalyst in the reaction. Explain why the student's claim is false.

Below is a mechanism proposed for the reaction of ozone in the upper atmosphere with nitrogen dioxide gas:

Step 1: 0_3 + $N0_2$ \rightarrow $N0_3$ + 0_2 (slow) Step 2: $N0_3$ + $N0_2$ \rightarrow N_20_5 (fast)

- 46. Identify the reaction intermediate.
- 47. What is the overall balanced equation for this process?
- 48. Write a rate law for this reaction based on the mechanism.
- 49. State the order of the reaction with respect to each of the reactants, as well as the overall order of the reaction.

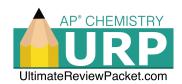
■ TOPIC 5.9- STEADY STATE APPROXIMATION ▶

A two step-mechanism for the synthesis of POl(g) is shown below. Answer the questions that follow.

Step 1: $PO(g) + I_2(g) \rightleftharpoons POI_2(g)$ (fast, equilibrium) Step 2: $PO(g) + POI_2(g) \rightarrow 2 POI(g)$ (slow)

- 50. What is the overall chemical reaction?
- 51. Identify any intermediates or catalysts involved in the mechanism.
- 52. In this mechanism, the rate determining step contains an intermediate. Explain why we cannot use a rate law that contains a reaction intermediate.
- 53. Identify a rate law that would be consistent with this mechanism.

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■ TOPIC 5.10- MULTISTEP REACTION ENERGY PROFILE •

The energy profile shown below represents the multistep mechanism for the substitution reaction of chlorine and methane to produce methyl

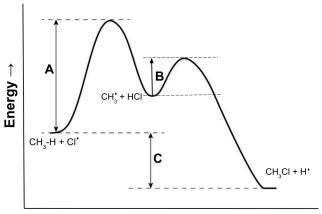
chloride: $2 CH_4(g) + CI_2(g) \rightarrow 2 CH_3CI + H_2(g)$

54. Is this reaction exothermic or endothermic? Explain.

55. How many steps are involved in this mechanism?

56. Which step is the rate determining step in the mechanism? Explain.

57. If this reaction was catalyzed, which letters would be affected? Explain.



Reaction Coordinate →

■ TOPIC 5.11- CATALYSIS •

A kinetics experiment studied the single replacement of halogens with the following three step mechanism:

Step 1: $CIO^- + H_2O \rightarrow HOCI + OH^-$ (slow)

Step 2: $Br^- + HOCI \rightarrow HOBr + CI^-$ (fast)

Step 3: $OH^- + HOBr \rightarrow H_2O + BrO^-$ (fast)

58. What is the chemical equation for the overall reaction?

59. What reaction intermediates are involved in this mechanism?

60. What is the catalyst involved in this mechanism?

A reaction mechanism for the decomposition of hydrogen peroxide is shown below:

Step 1: $H_2O_2 + I^- \rightarrow 0I^- + H_2O$ (slow) Step 2: $H_2O_2 + 0I^- \rightarrow I^- + H_2O + O_2$ (fast)

61. What is the overall balanced equation for the reaction represented by the mechanism?

62. Identify the reaction intermediate and the catalyst in this process.