

1. According to collision theory, what three criteria need to be met before a bimolecular reaction can take place? **Mark three answers on your scantron.** [S 02, ex 3]
- (a) The orientation probability factor must be 1.
 - (b) The collision energy must be \geq the activation energy for the reaction.
 - (c) The collision must occur in the proper orientation.
 - (d) The collision frequency must be \geq the frequency factor for the reaction.
 - (e) A collision between the reactants must occur.
2. Which one of the following statements is **FALSE**? [F 00, ex 3]
- (a) The activation energy for a one-step reaction is the energy required to reach the transition state.
 - (b) Rate constants always increase with temperature.
 - (c) The transition state for a reaction is the lowest energy structure intermediate between reactants and products.
 - (d) For similar bimolecular reactions, rate constants typically decrease as the size and complexity of the reactants increase.
 - (e) It is often found that the rates of reaction approximately double for every 10 °C increase in temperature.

For the next 4 questions, match the given definition to the following terms. Choose the best possible answer. [S 00, ex 3]

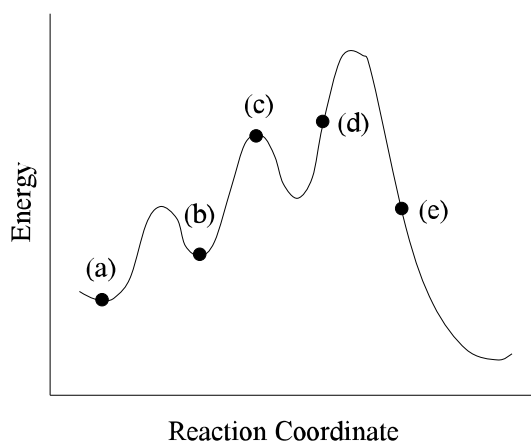
- | | |
|-----------------------------------|------------------------------------|
| (a) collision theory | (b) orientation probability factor |
| (c) reaction intermediate | (d) frequency factor, A |
| (e) ΔH_{rxn} | (ab) forward rate constant, k_f |
| (ac) reverse rate constant, k_r | (ad) transition state |
| (ae) kinetic molecular theory | (bc) activation energy, E_a |
3. The highest energy structure that is intermediate between reactant(s) and product(s) in a 1-step reaction.
4. The theory used to explain the concentration and temperature dependence of reaction rates.
5. The rate of effective collisions for a given reaction at a certain temperature.
6. The collision energy necessary for a reaction to occur.

For the next 4 questions, tell how the given change will affect the rate of an elementary reaction. The answer choices are [F 01, ex3]

- (a) increases the rate (b) decreases the rate (c) no change
7. An increase in temperature.
8. An increase in the activation energy for the reaction
9. An increase in the reactant concentration.
10. An increase in the size of one of the reactants in a bimolecular reaction.

Consider the reaction coordinate diagram shown below for the next three questions. [S 02, ex3]

11. Which one of the marked points in the diagram corresponds to a transition state?
12. Which one of the marked points in the diagram corresponds to a reaction intermediate?
13. How many elementary steps are involved in this reaction?
(a) 1 (b) 2 (c) 3 (d) 4 (e) 6

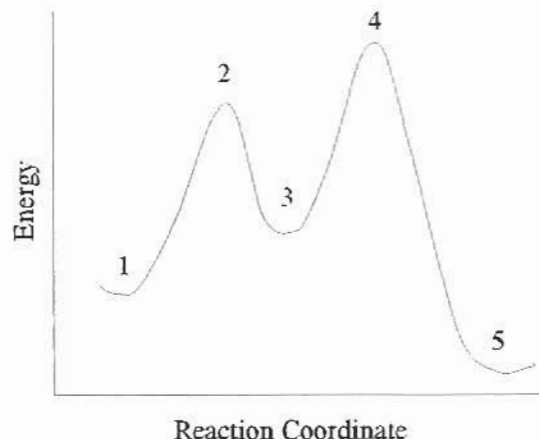


14. Which is the slow (rate-determining) step in the reaction?
(a) 1st set (b) 2nd step (c) 3rd step (d) 4th step (e) 6th step

Consider the adjacent reaction coordinate diagram for the next two questions.

[F 01, ex 3]

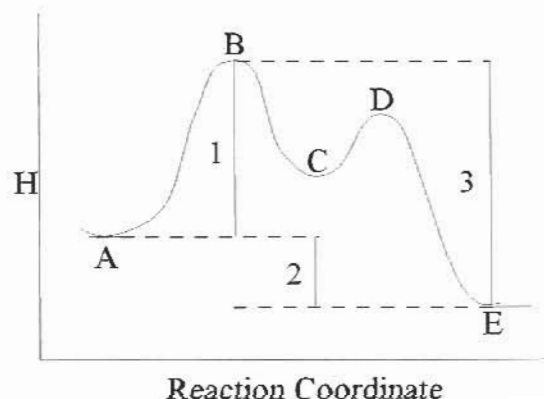
15. What is located at point 2 in the diagram?
- the reactants
 - the products
 - reaction intermediates
 - the transition state for the first step in the reaction mechanism.
 - the transition state for the second step in the reaction mechanism.



16. What is located at point 5 in the diagram?
- the reactants
 - the products
 - reaction intermediates
 - the transition state for the first step in the reaction mechanism.
 - the transition state for the second step in the reaction mechanism.

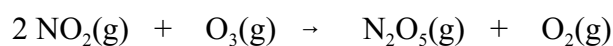
Consider the adjacent reaction coordinate diagram for the next two problems. [F 98, ex 3]

17. The enthalpy difference marked "1" in the reaction coordinate diagram corresponds to
- the activation energy of the forward reaction.
 - the activation energy of the reverse reaction.
 - the overall enthalpy change (ΔH) of the reaction.
 - the overall enthalpy change (ΔH) for the first step in the reaction.
 - the overall enthalpy change (ΔH) for the second step in the reaction.



18. The enthalpy difference marked "2" in the reaction coordinate diagram corresponds to
- the activation energy of the forward reaction.
 - the activation energy of the reverse reaction.
 - the overall enthalpy change (ΔH) of the reaction.
 - the overall enthalpy change (ΔH) for the first step in the reaction.
 - the overall enthalpy change (ΔH) for the second step in the reaction.

19. The rate law for the following reaction is $\text{rate} = k[\text{NO}_2][\text{O}_3]$. Which **one** of the following is a plausible mechanism for the reaction?



- (a) $\text{NO}_2 + \text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4$ fast
 $\text{N}_2\text{O}_4 + \text{O}_3 \rightarrow \text{N}_2\text{O}_5 + \text{O}_2$ slow
- (b) $2 \text{NO}_2 + \text{O}_3 \rightarrow \text{N}_2\text{O}_5 + \text{O}_2$
- (c) $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2$ slow
 $\text{NO}_3 + \text{NO}_2 \rightarrow \text{N}_2\text{O}_5$ fast
- (d) $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO} + \text{O}_4$ slow
 $\text{NO}_3 + \text{NO} \rightarrow \text{N}_2\text{O}_4$ fast
 $\text{N}_2\text{O}_4 + \text{O}_4 \rightarrow \text{N}_2\text{O}_5 + \text{O}_3$ fast

20. What is the rate law for the first step in mechanism (a) in the preceding question?

- (a) $\text{rate} = k[\text{NO}_2]^2$ (b) $\text{rate} = k[\text{N}_2\text{O}_4]$ (c) $\text{rate} = k[\text{N}_2\text{O}_4][\text{NO}_2]^{-2}$
(d) $\text{rate} = k[\text{NO}_2]$ (e) can not be determined

21. Consider the mechanism given in question 19, answer (a). What is the role of N_2O_4 in this mechanism?

- (a) product (b) reactant (c) transition state
(d) catalyst (e) reaction intermediate

22. The rate law for the following reaction $\text{rate} = k[\text{NO}]^2[\text{O}_2]$. Which **one** of the following mechanisms is most likely? (Hint: two mechanisms give the correct rate law, but one is much more likely than the other.) [Spr 99, ex 3]



- (a) $2\text{NO} + \text{O}_2 \rightarrow 2 \text{NO}_2$
- (b) $2 \text{NO} \rightleftharpoons \text{N}_2\text{O}_2$ fast equilibrium
 $\text{N}_2\text{O}_2 + \text{O}_2 \rightarrow 2 \text{NO}_2$ slow
- (c) $\text{NO} + \text{O}_2 \rightarrow \text{NO}_2 + \text{O}$ slow
 $\text{NO} + \text{O} \rightarrow \text{NO}_2$ fast
- (d) $\text{NO} + \text{O}_2 \rightarrow \text{NO}_3$ fast
 $\text{NO}_2 + \text{NO}_3 \rightarrow \text{N}_2\text{O}_5$ slow
- (e) $2 \text{NO} \rightarrow \text{N}_2\text{O}_2$ slow
 $\text{N}_2\text{O}_2 + \text{O}_2 \rightarrow 2 \text{NO}_2$ fast

Answers: 1 bce, 2 c, 3 ad, 4 a, 5 d, 6 bc, 7 a, 8 b, 9 a, 10 b, 11 c, 12 b, 13 c, 14 c, 15 d, 16 b, 17 a, 18 c, 19 c, 20 a, 21 e, 22 b.