Answers.

Chemistry 12 Rates of Reaction Worksheet #1

1. Consider: $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$

   If the rate of formation of NH_3 is 9.0×10^{-4} mol/s, then what is the rate of consumption of N_2? 4.5×10^{-4} mol/s

2. Suggest 2 specific changes that would increase the rate of rusting of a piece of iron.
   increase temperature, increase surface area of iron, increase O_2 concentration, add a catalyst

3. Consider:
   I concentration of reactants
   II temperature of reactants
   III surface area of reactants — not between 2 gases

   Which factor(s) affect the rate of a chemical reaction between 2 gases?

4. Consider: $2NO_{2(g)} \longrightarrow 2NO_{(g)} + O_{2(g)}$

   What is the rate of formation of O_2 if, under certain conditions, the rate of decomposition of NO_2 is 3.2×10^{-3} mol/sec? 1.6×10^{-3} mol/sec

5. Consider:
   I $N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$ Homogeneous reaction
   II $2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$
   III $CaCO_{3(s)} + 2H^+_{(aq)} \longrightarrow Ca^{2+}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

   Which reaction rate(s) will increase if the surface area is increased?

6. Consider:
   I frequency of successful collisions
   II volume of reaction vessel
   III pressure of the system
   IV mass of system

   Which condition(s) must increase to increase the rate of the reaction?

7. Consider:
   I pressure per mole
   II energy consumed per mole
   III volume of gas per unit time
   IV moles formed per litre of solution

   Which is(are) an expression of the rate of a chemical reaction?

8. Give an example of a heterogeneous reaction and list four different factors that affect the rate of this reaction.

   $Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$

   1. Temperature
   2. Concentration of HCl
   3. Surface area of Mg

9. Consider the reaction:

$$C_2H_{4(g)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 2H_2O$$

At certain conditions, 0.15 mol CO_2 is produced in 2.0 minutes. What is the rate of consumption C_2H_4 of in g/s? $0.15\ mol\ CO_2 \times \frac{1\ mol\ C_2H_4}{2\ mol\ CO_2} = 0.075\ mol\ C_2H_4$ in 2.0 min.

10. Consider the following reaction: $0.075\ mol \times \frac{28.0\ g}{1\ mol} = 2.1\ g$ in $120\ s = 0.018\ g/s$

$$C_{12}H_{22}O_{11(s)} \longrightarrow 11\ H_2O_{(g)} + 12C_{(s)}$$

The rate of decomposition of $C_{12}H_{22}O_{11(s)}$ is 0.75 mol/min. What mass of C is produced in 10.0 seconds? $0.75\ mol/min \times \frac{12\ mol\ C}{1\ mol\ C_{12}H_{22}O_{11}} = 9.0\ mol/60\ s = 9.0\ mol \times \frac{12.0\ g}{1\ mol} = 108/60 = 18\ g$ in $10\ s$

11. The mass of a burning candle is monitored to determine the rate of combustion of paraffin. An accepted reaction for the combustion of paraffin is:

$$2C_{28}H_{58(s)} + 85O_{2(g)} \longrightarrow 58\ H_2O_{(g)} + 56CO_{2(s)}$$

a) Calculate the average rate of consumption of paraffin in g/min for the time interval 12.0 to 24.0 minutes. $24.5 - 23.4\ g = 1.1 / 12.0\ min = 0.092\ g/min$

FW $C_{28}H_{58} = 394.0\ g/mol$

b) Calculate to rate of CO_2 production in mol/min for the time interval 12.0 to 24.0 minutes. $0.092\ g \times \frac{1\ mol}{394.0\ g} = 2.34 \times 10^{-4}\ mol/min$

$2.34 \times 10^{-4}\ mol \times \frac{56\ mol\ CO_2}{2\ mol\ C_{28}H_{58}} = 6.5 \times 10^{-3}\ mol/min$

The following data is observed:

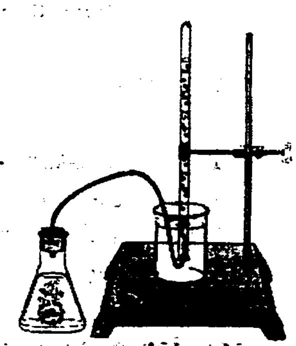
[illegible]	[illegible]
0.0	25.6
6.0	25.1
12.0	24.5
18.0	23.9
24.0	23.4
30.0	22.8

12. An Alka-seltzer tablet is added to water to produce carbon dioxide gas. The gas was collected using water displacement.

a) Calculate the average rate of reaction for the formation of CO_2 gas for the times:

i) 0-10 seconds $\frac{3.0\ mL}{10.0\ s} = 0.30\ mL/s$

ii) 10-20 seconds $\frac{20.0 - 3.0}{10.0\ s} = 1.70\ mL/s$



The following data is recorded:

Time (s)	Volume of CO_2 (mL)
0.0	0
10.0	3.0
20.0	20.0
30.0	33.5
40.0	43.0
50.0	43.0
60.0	43.0

b) Suggest a reason why the rate of reaction from 0-10 seconds is slower than the rate from 10.0-20.0 seconds. The tablet was intact (whole) from 0-10 s meaning a smaller surface area and thus a slower rate, whereas from 10-20 s the tablet broke apart, increasing SA and thus increasing collision frequency and rate.

c) The rate of reaction is not constant during the entire interval from 10.0 s to 40.0 s. Describe the change in rate and explain a reason for the change.

Time interval	Rate
10.0 - 20.0 s	1.70 mL/s
20.0 - 30.0 s	1.35 mL/s
30.0 - 40.0 s	0.95 mL/s

The rate decreases from 10.0 - 40.0 s.

The [reactant] decreased as the tablet was consumed, resulting in decreased collision frequency & thus decreased rate.

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Reaction Rates

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A. Potential Energy Diagrams

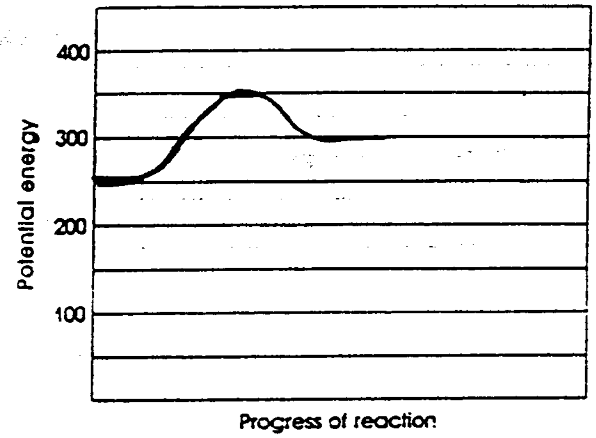
The potential energy of substances involved in a reaction can be plotted versus the progress of the reaction, as the process moves from initial reactants, through activated complex, to final products.

On the grids below, plot energy diagrams for 1-3 below, given the following information, and answer the questions. For number 4, study the energy diagram and answer the questions.

1. Potential energy of reactants: 250
   Potential energy of activated complex: 350
   Potential energy of products: 300
   Is the reaction exothermic or endothermic? How can you tell? What is the value of ΔH?

   endothermic, products have more potential energy than reactants

   $\Delta H = +50$



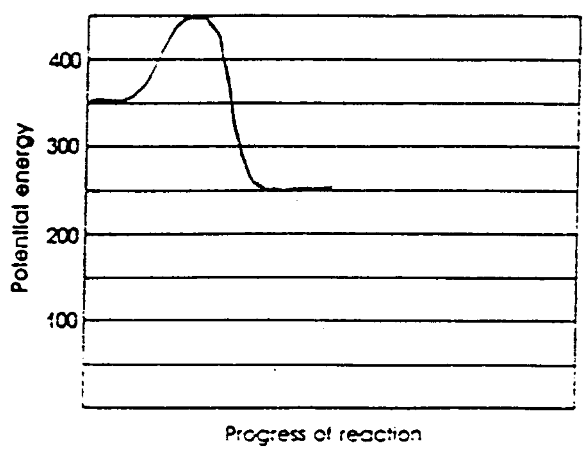
If a catalyst were added, what would happen to the diagram? What would happen to the energies of reactants, products, and activated complex, and to the rate? Explain the effect on the rate.

Catalyst lowers the energy of the activated complex, more particles will have sufficient energy to react and the rate will increase. The energies of reactants and products will not change.

2. Potential energy of reactants: 350
   Activation energy (energy needed to form activated complex from reactants): 100
   Potential energy of products: 250
   Is this reaction exothermic or endothermic? Why? What is the value of ΔH?

   exothermic, the products have less potential energy than reactants.

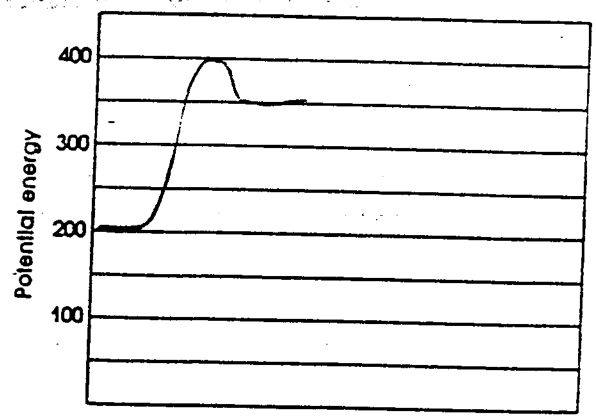
   $\Delta H = -100$



What is the potential energy of the activated complex? 450

If the concentration of the reactants were increased, what would happen to the diagram? What would happen to the energies of reactants, products, and activated complex, and to the rate? Explain the effect on the rate. Increasing the concentration would not change the diagram or the energies of reactants, products, or activated complex. The rate would increase because more particles would be available to collide.

3. Potential energy of reactants: 200
Potential energy of activated complex: 400
ΔH = +150
Is this reaction exothermic or endothermic? Why?
endothermic, ΔH is positive

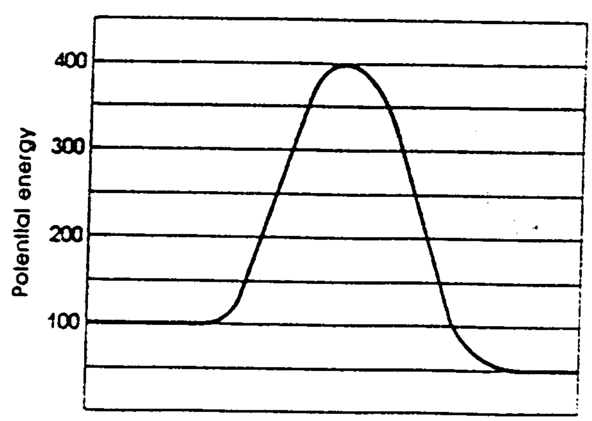


What is the potential energy of the products?
350

What is the activation energy? 200

If temperature were increased, what would happen to the diagram? What would happen to the energies of reactants, products, and activated complex, and to the rate? Explain the effect on the rate.
The diagram, energies of reactants, products and activated complex would be unchanged. The rate would increase because more particles would have enough kinetic energy to form the activated complex.

4. Potential energy of reactants: 100
Potential energy of activated complex: 400
Activation energy: 300
Potential energy of products: 50
ΔH: −50



Is the reaction exothermic or endothermic? Why? Exothermic, the products have less potential energy than the reactants complex, and to the rate. Explain the effect on the rate.

The energies would be unchanged but the rate would decrease. Inhibitors decrease the concentration of reactants, decreasing collision frequency + rate

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B. Factors Affecting Rate

The rates of chemical reactions depend upon a number of factors. These factors can be controlled by scientists in order to cause processes to proceed at desired rates. For each of the following factors, write its probable effect (increase, decrease, no effect) on rate, and then explain the effect on the basis of collision theory.

FACTOR	EFFECT ON RATE	EXPLANATION
decreased concentration	decreased	lower collision frequency
increased gas pressure	increased	greater collision frequency
decreased temperature	decreased	lower kinetic energy, fewer particles with exceed the energy threshold
decreased surface area	decreased	lower collision frequency
addition of catalyst	increased	introduces alternate mechanism requiring a lower activation mechanism
addition of inhibitor	decreased	see above

Rates of Reaction #3

Key.

Chemistry 12

Reaction Mechanisms Worksheet

1. Examine the following reaction mechanism:

Step 1: $OCl^- + \cancel{H_2O} \longrightarrow HOCl + OH^-$

Step 2: $HOCl + I^- \longrightarrow HOI + Cl^-$

Step 3: $HOI + OH^- \longrightarrow H_2O + OI^-$

(a) Identify the catalyst in the mechanism and explain how you were able to make your identification. H_2O, is used up in step 1 but regenerated in step 3

(b) Explain why OH^- would be called a reaction intermediate.
It is made in step one but used up in step 3

(c) List any additional reaction intermediates.
HOCl, HOI

2. The reaction between NO_2 and CO is slow and has the overall equation:

$$NO_{2(g)} + CO_{(g)} \longrightarrow NO_{(g)} + CO_{2(g)}$$

One step in the two-step mechanism of this reaction is:

$$CO_{(g)} + NO_{3(g)} \longrightarrow NO_{2(g)} + CO_{2(g)} \qquad \text{FAST}$$

(a) Write the equation for the other step in the mechanism.
$NO_2 + NO_2 \rightarrow NO + NO_3$

(b) State whether your proposed step is slow or fast and explain your choice.
Slow, the overall reaction is slow and the other step is fast

3. The proposed mechanism for a reaction is:

Step 1: $CH_3OH + HCl \longrightarrow CH_3^+ + H_2O + Cl^-$

Step 2: $CH_3^+ + Cl^- \longrightarrow CH_3Cl$

(a) What is the overall reaction being studied?
$CH_3OH + HCl \rightarrow H_2O + CH_3Cl$

(b) List any reaction intermediates.
CH_3^+, Cl^-

4. The proposed mechanism for a reaction is:

Step 1: $NO_2Cl \longrightarrow NO_2 + Cl$ slow

Step 2: $NO_2Cl + Cl \longrightarrow NO_2 + Cl_2$ fast

(a) Describe the overall reaction.

$2NO_2Cl \rightarrow 2NO_2 + Cl_2$ slow

Key.

5. Consider the following fast reaction:

$H^+ + I^- + H_2O_2 \longrightarrow H_2O + HOI$

A student proposes the following two-step mechanism for the above fast reaction:

Step 1: $H^+ + H^+ + H_2O_2 \longrightarrow H_4O_2^{2+}$
Step 2: $H_4O_2^{2+} + I^- \longrightarrow H_2O + HOI + H^+$

Would you agree or disagree with the proposed mechanism? Explain.
Disagree, step 1 involves a 3 particle collision, which is unlikely especially in a fast rx

6. Consider the following reaction:

$CO + NO_2 \longrightarrow CO_2 + NO$

(a) The first step in each of two proposed reaction mechanisms for the above reaction is listed below. If each proposed reaction mechanism consists of only two steps, determine the second step for each mechanism.

proposed mechanisn one:
Step 1: $2NO_2 \longrightarrow NO_3 + NO$ SLOW
Step 2: $CO + NO_3 \longrightarrow NO_2 + CO_2$ FAST

proposed mechanism two:
Step 1: $2NO_2 \longrightarrow N_2O_4$ FAST
Step 2: $N_2O_4 + CO \longrightarrow CO_2 + NO + NO_2$ SLOW

(b) Experimental data shows that the rate of the reaction is <u>not</u> affected by a change in the CO concentration. Which of the two proposed reaction mechanisms would be consistent with the data? Explain. The first mechanism. CO is not a reactant in the rate determining step of this mechanism.

7. Consider the following reaction mechanism:

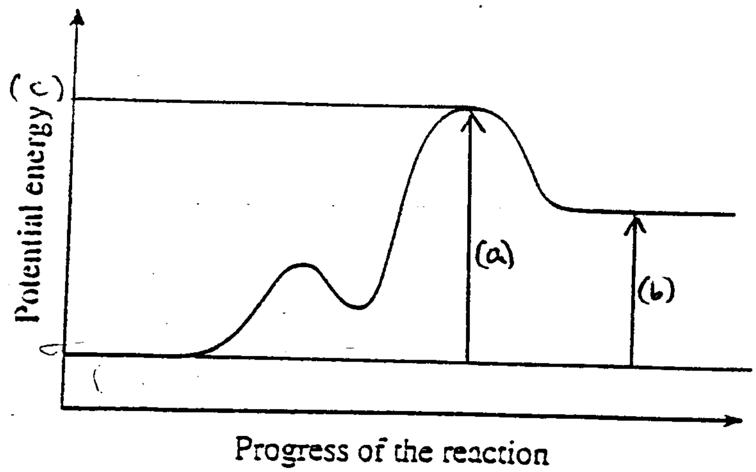
Step 1: $NO_2 + Mn \longrightarrow NO_2Mn$
Step 2: $NO_2Mn + NO_2 \longrightarrow NO_3 + NO + Mn$
STep 3: $NO_3 + CO \longrightarrow NO_2 + CO_2$

(a) Identify the catalyst. Mn, NO_2
(b) Identify a reaction intermediate. NO_2Mn, NO_3
(c) Identify the products of the overall reaction. NO, CO_2

Key.

Rates of Reaction #4

1. On the following diagram, clearly label the:
   (a) activation energy for the forward reaction
   (b) heat of reaction
   (c) energy of the activated complex in the rate determining step



2. The following series of steps describes a reaction mechanism for a chemical reaction:

step 1:	$H_2O_2 + H^+ \longrightarrow H_3O_2^+$	fast
step 2:	$H_3O_2^+ + I^- \longrightarrow H_2O + HOI$	slow
step 3:	$HOI + I^- \longrightarrow OH^- + I_2$	fast
step 4:	$OH^- + H^+ \longrightarrow H_2O$	fast
step 5:	$I_2 + I^- \longrightarrow I_3^-$	fast

$$H_2O_2 + 3I^- + 2H^+ \longrightarrow 2H_2O + I_3^-$$

Intermediates: $H_3O_2^+$, HOI, OH^-, I_2

Write the equation for the overall reaction and identify all reaction intermediates. Increasing the concentration of which reactant will greatly increase the rate of the reaction? Explain. Increasing concentration of I^- will increase the rate because it is a reactant in step 2, the slow or rate determining step.

3. Describe two ways, other than the use of a catalyst, to increase the rate of the following reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

any 2 of:
① powder the solid zinc
② increase the concentration of $HCl_{(aq)}$
③ heat the mixture

4. Consider the following uncatalyzed reaction which is a one-step process:

$$2Ce^{4+} + Tl^{+} \longrightarrow 2Ce^{3+} + Tl^{3+}$$

When a catalyst is added to the above reaction, the following three-step reaction mechanism takes place:

step 1: $Ce^{4+} + Mn^{2+} \longrightarrow Ce^{3+} + Mn^{3+}$

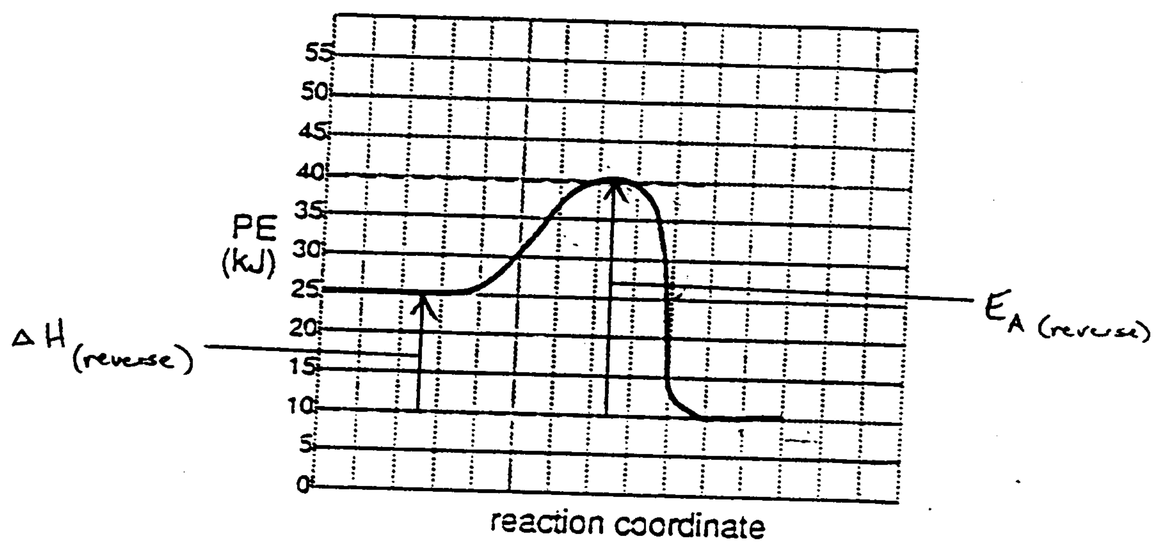
step 2: $Ce^{4+} + Mn^{3+} \longrightarrow Ce^{3+} + Mn^{4+}$

step 3: $Mn^{4+} + Tl^{+} \longrightarrow Tl^{3+} + Mn^{2+}$

With reference to the above equation, use collision theory to explain why the catalyzed reaction mechanism is faster than the uncatalyzed reaction.

The catalyzed mechanism involves only 2 particle collisions which will be faster than the uncatalyzed 3 particle collision.

5. Consider the following diagram:



(a) On the diagram, label the change in enthalpy and the activation energy for the reverse reaction.

(b) Give the values for the energy of the activated complex and the ΔH for the forward reaction.

E_p (activated complex) = 40 kJ $\Delta H_{(forward)}$ = −15 kJ

6. Consider the following reaction:

$$CO_{(g)} + NO_{2(g)} \longrightarrow CO_{2(g)} + NO_{(g)}$$

Using collision theory, explain why the rate of the reaction decreases as the reaction proceeds.

As the reaction proceeds the concentrations of CO and NO_2 decrease so the rate of the reaction decreases due to fewer particles of reactant available for collision.

2.

7. Consider the following mechanism for an exothermic reaction:

step 1:	$NO_{(g)} + NO_{(g)} \longrightarrow N_2O_{4(g)}$	fast
step 2:	$N_2O_{4(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$	slow
	$2NO + O_2 \rightarrow 2NO_2$	

See diagram — Draw a PE diagram to represent the above two step reaction mechanism and write the net equation to represent the overall reaction.

8. The uncatalyzed decomposition of methanoic acid, HCOOH, has a $\Delta H = 13$ kJ and the activation energy = 88 kJ.
The reaction mechanism for the catalyzed decomposition of methanoic acid is:

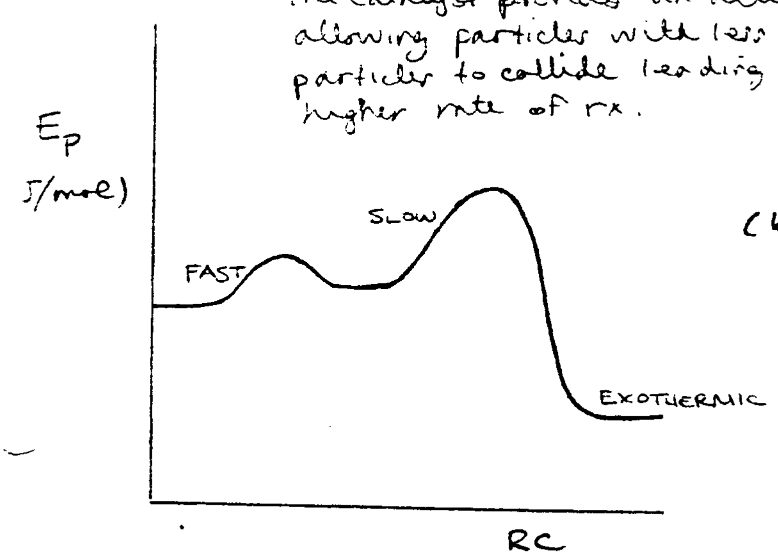
step 1:	$HCOOH + H^+ \longrightarrow HCOOH_2^+$	fast
step 2:	$HCOOH_2^+ \longrightarrow HCO^- + H_2O$	slow
step 3:	$HCO^- \longrightarrow H^+ + CO$	fast

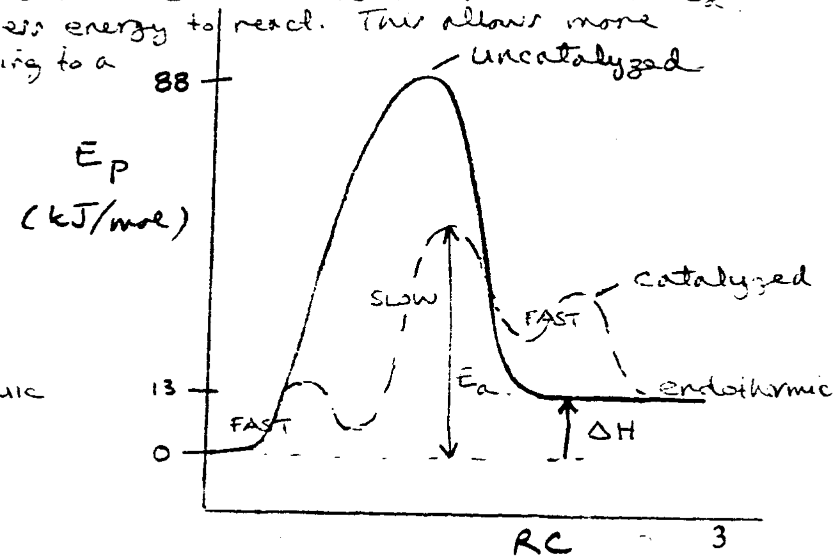
See below right On a graph draw a PE diagram for the catalyzed decomposition of methanoic acid. Label the ΔH and the activation energy for the reaction.

9. The following equations represent a proposed mechanism for the decomposition of ozone:

step 1:	$\cancel{Cl} + O_3 \longrightarrow \cancel{ClO} + O_2$
step 2:	$\cancel{ClO} + O \longrightarrow \cancel{Cl} + O_2$
	$O_3 + O \rightarrow 2O_2$

Write the equation for the overall reaction.
Identify the catalyst. Cl
Explain how the catalyst increases the rate of this reaction.
The catalyst provides an alternative rx. mech with a lower Ea allowing particles with less energy to react. This allows more particles to collide leading to a higher rate of rx.





Answer Key

1. Given the following reaction:

$$2NaOCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + O_{2(g)}$$

The catalyst $Co_2O_{3(s)}$ is added to the above reaction and the system is closed. Which of the following properties could be monitored in order to determine reaction rate?

A. Pressure.
B. Mass of Co_2O_3.
C. Concentration of Na^+.
D. Concentration of Co_2O_3.

2. The following equation represents the reaction between copper metal and aqueous silver nitrate solution:

$$Cu_{(s)} + 2AgNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$$

brown colourless blue grey

Which of the following properties would <u>best</u> monitor the rate of this reaction?

A. Concentration of NO_3^-
B. Gas pressure.
C. Colour of solution.
D. Mass of the system.

3. Which of the following quantities, when graphed, can be used to determine a reaction rate?

A. Colour vs. density.
B. Gas volume vs. time.
C. Pressure vs. temperature.
D. Mass vs. activation energy.

4. Which of the following reactions would be expected to have the fastest rate at room temperature?

A. $Hg_{(l)} + Br_{2(l)} \longrightarrow HgBr_{2(g)}$
B. $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$
C. $Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$
D. $4NH_{3(g)} + 7O_{2(g)} \longrightarrow 4NO_{2(g)} + 6H_2O_{(g)}$

5. Which of the following reactions is <u>MOST LIKELY</u> to have the greatest rate at room temperature?

A. $Pb^{2+}_{(aq)} + 2Cl^-_{(aq)} \longrightarrow PbCl_{2(s)}$
B. $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$
C. $C_2H_{4(g)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 2H_2O_{(g)}$
D. $Zn_{(s)} + S_{(s)} \longrightarrow ZnS_{(s)}$

6. Which one of the following reactions would be expected to proceed at the greatest rate at room temperature?

A. $Mg_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow MgO_{(s)}$
B. $Br_{2(g)} + Cl_{2(g)} \longrightarrow 2BrCl_{(g)}$
C. $2Ag^+ + CrO_4^{2-} \longrightarrow Ag_2CrO_4$
D. $2BrO_3^- + 10\,Fe^{2+} + 12\,H^+ \longrightarrow 10\,Fe^{3+} + Br_2 + 6\,H_2O$

7. Increasing temperature results in an increase in reaction rate. This is due to

A. an increase in ΔH.
B. an alternate reaction path.
C. a decrease in activation energy.
D. an increase in the fraction of particles possessing sufficient energy.

8. Consider the following reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

The rate of the above reation is dependent on
A. temperature only.
B. surface area only.
C. temperature and surface area.
D. temperature, surface area, and pressure.

9. Which factor(s) affects the rate of a homogeneous reaction?
A. Concentration only.
B. Temperature and concentration.
C. Temperature and surface area.
D. Temperature, concentration, and surface area.

10. Consider the following reaction:

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)} + 112 \text{ kJ}$$

The rate of the above reaction could be increased by
A. an increase in [NO].
B. a decrease in pressure.
C. a decrease in temperature.
D. an increase in surface area.

11. Consider the following reaction occurring in a closed container:

$$Br_{2(g)} + Cl_{2(g)} \longrightarrow 2BrCl_{(g)} \quad \Delta H = -61 \text{ kJ}$$

Which change will increase the frequency of effective collisions between Br_2 and Cl_2 molecules?
A. Remove some BrCl.
B. Decrease the pressure.
C. Increase the temperature.
D. Increase the container volume.

12. An increase in concentration of a reactant increases reaction rate. This increase in reaction rate is due to
A. an increase in ΔH.
B. an increase in kinetic energy.
C. a decrease in activation energy.
D. an increase in frequency of successful collisions.

13. Consider the following reaction:

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)} \div 112 \text{ kJ}$$

The rate of the above reaction could be decreased by
A. an increase in [NO].
B. a decrease in pressure.
C. an increase in temperature.
D. a decrease in surface area.

14. One way of increasing the rate of a reaction is to
A. increase the activation energy of the reaction.
B. increase the frequency of collisions of reactant molecules.
C. decrease the overall enthalpy change of the reaction.
D. increase the potential energy of the activated complex.

15. Which would be the best procedure to use to increase the rate of the following reaction?

$PCl_{5(g)} \longrightarrow PCl_{3(g)} + Cl_{2(g)}$

A. Increase surface area.
B. Increase temperature.
C. Decrease temperature.
D. Decrease pressure.

16. When reacting zinc with sulphuric acid, which experimental conditions would be expected to result in the greatest rate?

A. 0.50 M H_2SO_4, powdered Zn, 50°C.
B. 1.0 M H_2SO_4, powdered Zn, 50°C.
C. 1.0 M H_2SO_4, block of Zn, 50°C.
D. 1.0 M H_2SO_4, powdered Zn, 25°C.

17. If all other factors were equal, what effect would a decrease in activation energy have on the reaction rate?

A. Increase the rate.
B. Decrease the rate.
C. No effect on the rate.
D. Drop the rate to zero.

18. Consider this reaction:

$$H_{2(g)} + I_{2(g)} \longrightarrow 2HI_{(g)}$$

What happens to the potential energy and the kinetic energy as a molecule of H_2 approaches a molecule of I_2?

A. The PE and the KE increase.
B. The PE and the KE decrease.
C. The PE increases and the KE decreases.
D. The PE decreases and the KE increases.

19. A solution of acid is added to a solution of base, resulting in an increase in temperature. This result indicates that the acid-base reaction is

A. exothermic and ΔH is positive.
B. exothermic and ΔH is negative.
C. endothermic and ΔH is positive.
D. endothermic and ΔH is negative.

20. A two-step reaction mechanism has at least

A. one reaction intermediate and one activated complex.
B. two reaction intermediates and one activated complex.
C. one reaction intermediate and two activated complexes.
D. two reaction intermediates and two activated complexes.

21. The activation energy of a reaction is determined by the

A. nature of reactants.
B. temperature of reactants.
C. surface area of reactants.
D. concentration of reactants.

22. An activated complex may be described as a molecular species which is

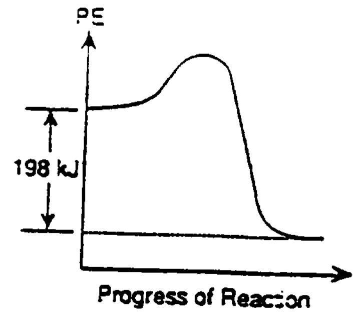
A. long-lived and has low PE.
B. short-lived and has low PE.
C. short-lived and has high PE.
D. long-lived and has high PE.

23. Consider this reaction:

$$O_{3(g)} + NO_{(g)} \longrightarrow O_{2(g)} + NO_{2(g)} + 198\ kJ$$

The energy diagram which best describes this reaction is

A.



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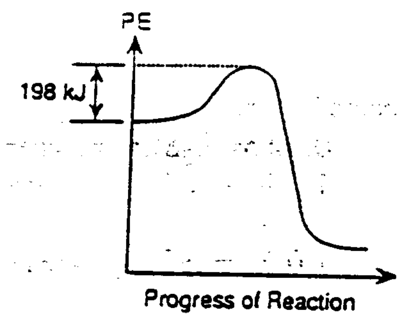
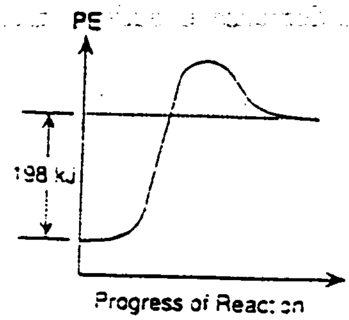
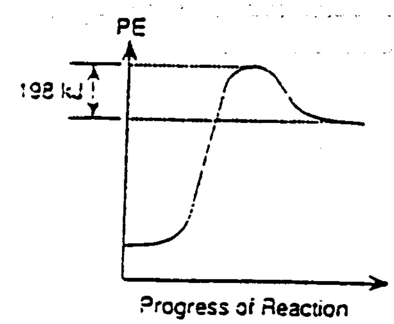


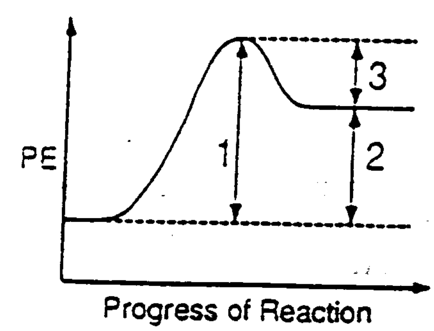
C.



D.



Use the following diagram to answer question 24.



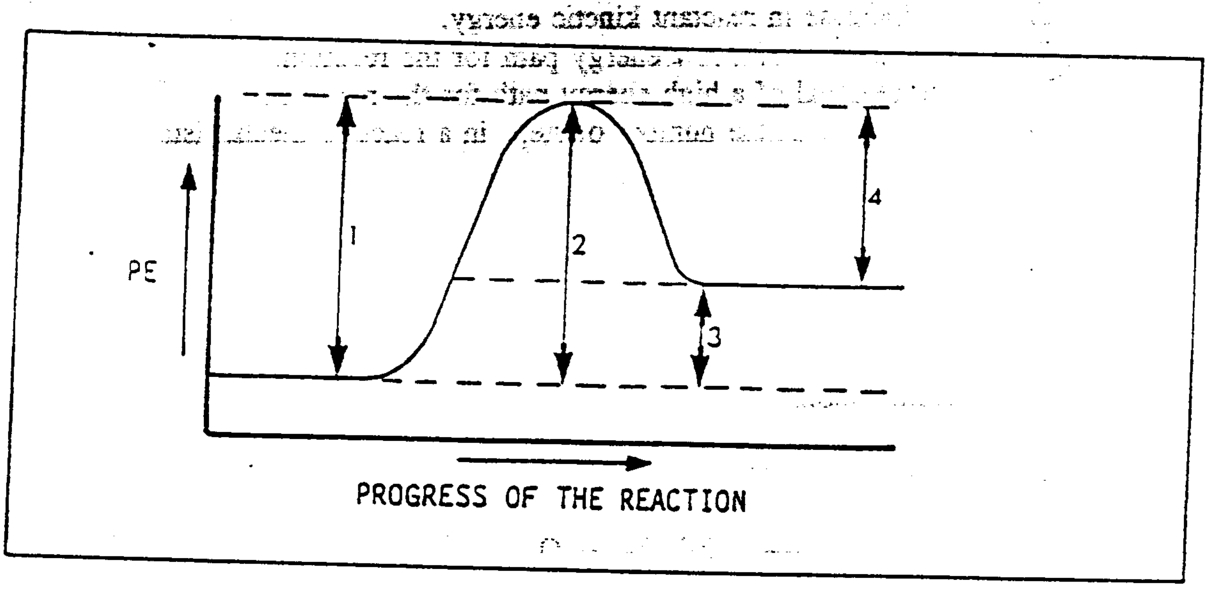
24. Consider the above potential energy diagram. The intervals which represent ΔH and the activation energy of the forward reaction are

A. ΔH is interval 1 and activation energy is interval 3.
B. ΔH is interval 1 and activation energy is interval 2.
C. ΔH is interval 2 and activation energy is interval 3.
D. ΔH is interval 2 and activation energy is interval 1.

25. Which statement is true about the activated complex?

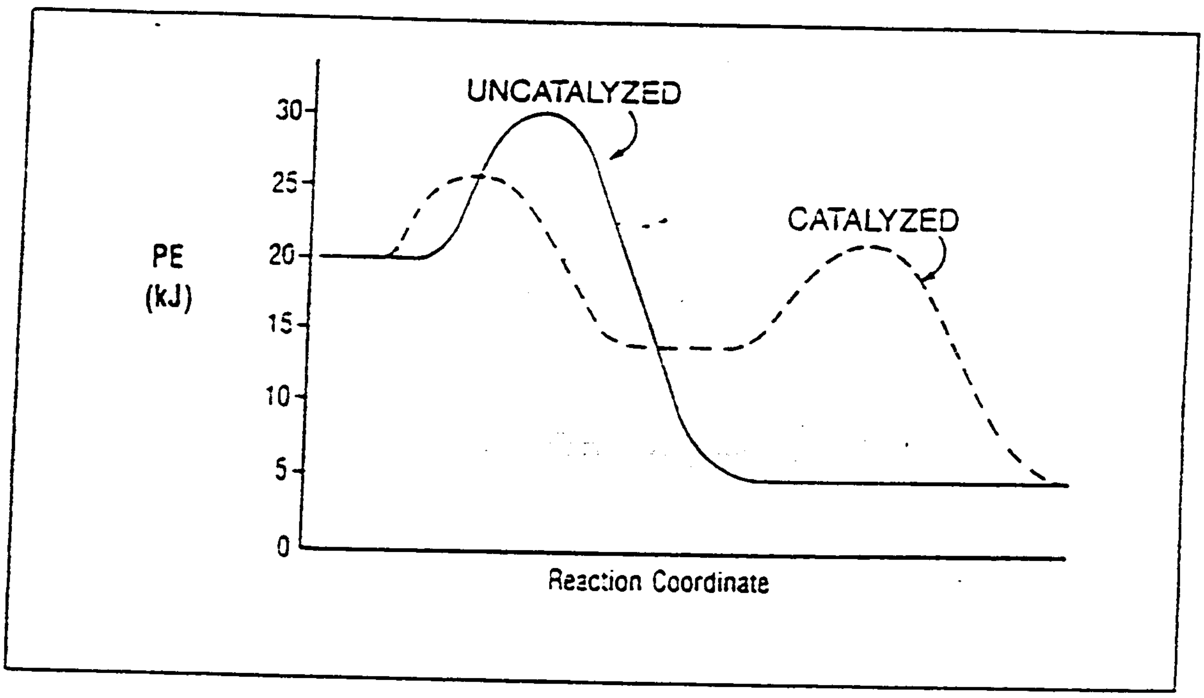
A. It acts as a catalyst.
B. It is a stable compound.
C. It always forms products.
D. It posesses more potential energy than the reatants or the products.

Use the following energy diagram to answer question 26.



26. Which interval in the above potential energy diagram represents the ▲H value for the reaction?
   A. 1
   B. 2
   C. 3
   D. 4

Use the following diagram to answer questions 27 and 28.



27. Given the above potential energy diagram for a catalyzed and uncatalyzed reaction, the ▲H for the forward catalyzed reaction is
   A. -20 kJ
   B. -15 kJ
   C. 5 kJ
   D. 15 kJ

28. The activation energy for the forward uncatalyzed reaction is
   A. 10 kJ
   B. 15 kJ
   C. 25 kJ
   D. 30 kJ

29. The effect of a catalyst is thought to be due to
   A. an increase in reactant kinetic energy.
   B. the addition of a low energy path for the reaction.
   C. the removal of a high energy path for the reaction.
   D. a decrease in the number of steps in a reaction mechanism.

30. Which of the following is a common commercial catalyst?
   A. Octane.
   B. Krypton.
   C. Platinum.
   D. Hemoglobin.

31. Consider the following equation:

$$2H_2O_{2(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$$

When a piece of raw potato was added to the above reaction, the reaction rate increased dramatically. An enzyme in the potato was found to be responsible for the increase in the reaction rate. In this reaction, the enzyme would be referred to as
   A. a catalyst.
   B. an inhibitor.
   C. an activated complex.
   D. a reaction intermediate.

32. Which statement is true about what occurs after a catalyst has been added to a system?
   A. The forward reaction rate only will increase.
   B. The reverse reaction rate only will increase.
   C. The forward and reverse reactions will both increase.
   D. The forward and reverse reaction rates will both remain unchanged.

33. A reaction mechanism is
   A. the order in which the chemicals are mixed together.
   B. the experimental apparatus used for a chemical reaction.
   C. the combination of reactants used to carry out a reaction.
   D. the series of collisions resulting in the overall reaction.

34. Which step in a reaction mechanism determines the rate?
   A. The last step.
   B. The first step.
   C. The fastest step.
   D. The slowest step.

35. Use the following reaction to answer this question:

$$A + B \longrightarrow C$$
$$C + K \longrightarrow D + A$$
$$D \longrightarrow M + N$$

In the above reaction mechanism, which species is acting as a catalyst?
   A. A
   B. B
   C. C
   D. D

36. Consider this two-step reaction mechanism:

Step 1 $H_2O_2 + I^- \longrightarrow H_2O + IO^-$
Step 2 $H_2O_2 + IO^- \longrightarrow H_2O + O_2 + I^-$

The reaction intermediate is
A. I^-
B. O_2
C. IO^-
D. H_2O

Use the three-step reaction mechanism below to answer questions 37 and 38.

step 1: $N_2 + 2O_2 \longrightarrow 2NO_2$
step 2: $2NO_2 \longrightarrow NO_3 + NO$
step 3: $NO_3 + CO \longrightarrow NO_2 + CO_2$

37. A reaction intermediate is
A. O_2
B. NO
C. CO
D. NO_3

38. The overall reaction from the three steps shown above is
A. $CO + NO_3 \longrightarrow CO_2 + NO_2$
B. $N_2 + O_2 + CO \longrightarrow NO + NO_2 + CO_2$
C. $N_2 + 2O_2 + CO \longrightarrow NO + NO_2 + CO_2$
D. $N_2 + O_2 + CO_2 + NO_2 \longrightarrow NO + 2NO_2 + CO_2$

39. For the overall reaction $OCl^- + I^- \longrightarrow OI^- + Cl^-$

the mechanism is:
Step 1 $OCl^- + H_2O \longrightarrow HOCl + OH^-$
Step 2 $I^- + HOCl \longrightarrow HOI + Cl^-$
Step 3 $HOI + \underline{\ ?\ } \longrightarrow H_2O + OI^-$

The missing particle in step 3 is
A. Cl^-
B. OH^-
C. OCl^-
D. $HOCl$

40. The reaction $2A + B + C \longrightarrow D$ takes place through the following mechanism in which I_1 and I_2 represent reaction intermediates.

Step 1 (slow) $A + B \longrightarrow I_1$
Step 2 (fast) $I_1 + A \longrightarrow I_2$
Step 3 (fast) $I_2 + C \longrightarrow D$

How can you produce a significant increase in the rate of the overall reaction?
A. Increase [B].
B. Decrease [B].
C. Increase [C].
D. Decrease [A].

Review #1 key

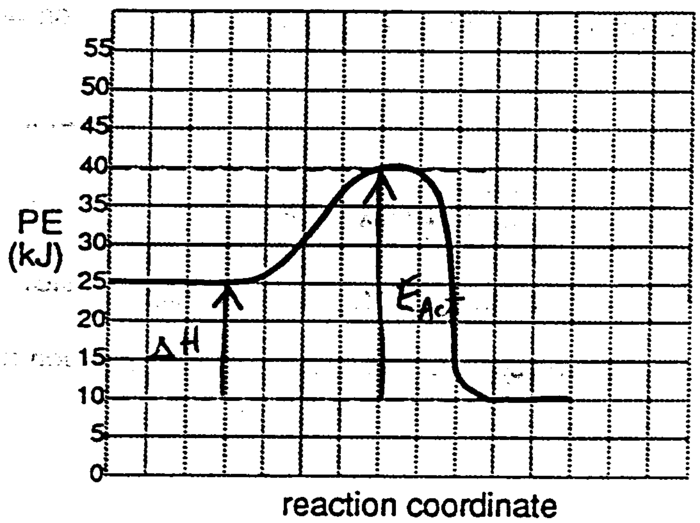
1. The following series of steps describes a reaction mechanism for a chemical reaction:

Step 1.	$H_2O_2 + H^+ \longrightarrow H_3O_2^+$	fast
Step 2.	$H_3O_2^+ + I^- \longrightarrow H_2O + HOI$	slow
Step 3.	$HOI + I^- \longrightarrow OH^- + I_2$	fast
Step 4.	$OH^- + H^+ \longrightarrow H_2O$	fast
Step 5.	$I_2 + I^- \longrightarrow I_3^-$	fast

Write the equation for the overall reaction and identify all the reaction intermediates. Increasing the concentration of which reactant will greatly increase the rate of the reaction? Explain. $H_2O_2 + 2H^+ + 3I^- \longleftrightarrow 2H_2O + I_3^-$

Intermediates are: $H_3O_2^+$, HOI, OH^- and I_2. Increasing conc. I^- will increase rate as it is a reactant for step 2 - the rate determining step.

2. Consider the following potential energy diagram:



(a) On the diagram, label the change in enthalpy and the activation energy for the reverse reaction.

(b) Give the values for:

i) the energy of the activated complex. 40 kJ

ii) ▲H for the forward reaction. - 15kJ

3. Describe **TWO** ways, other than the use of a catalyst, to increase the rate of the following reaction:

$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

increase [HCl]

heat up mixture

increase surface area of Zn(s)

Key,

4. Consider the following uncatalyzed reaction which is a one-step (elementary) process:

$2Ce^{4+} + Tl^{+} \longrightarrow 2Ce^{3+} + Tl^{3+}$

When a catalyst is added to the above reaction, the following three step reaction mechanism takes place:

Step 1. $Ce^{4+} + Mn^{2+} \longrightarrow Ce^{3+} + Mn^{3+}$

Step 2. $Ce^{4+} + Mn^{3+} \longrightarrow Ce^{3+} + Mn^{4+}$

Step 3. $Mn^{4+} + Tl^{+} \longrightarrow Tl^{3+} + Mn^{2+}$

With reference to the above equation, use collision theory to explain why the catalyzed reaction mechanism is faster than the uncatalyzed reaction.

The catalyzed mechanism involves a rapid series of 2-particle collisions which require a lower activation energy than the slower 3 particle mechanism more particles have enough E_K to react and the rate increases

5. Consider the following reaction:

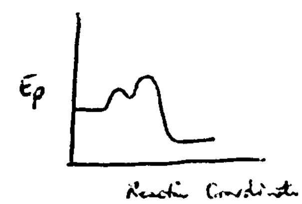
$CO_{(g)} + NO_{2(g)} \longrightarrow CO_{2(g)} + NO_{(g)}$

Using collision theory, explain why the rate of the reaction decreases as the reaction proceeds. As the reaction proceeds the concentrations of CO and NO_2 decrease, this decreases the collision frequency which results in a lower rate of reaction

6. Consider the following mechanism for an exothermic reaction:

Step 1. $NO_{(g)} + NO_{(g)} \longrightarrow N_2O_{2(g)}$ fast

Step 2. $N_2O_{2(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$ slow



Draw a PE diagram to represent the above two step reaction mechanism and write the net equation to represent the overall reaction.

$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ slow

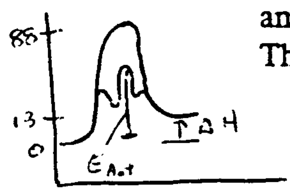
7. The uncatalyzed decomposition of methanoic acid, HCOOH, has a ΔH of +13 kJ and an activation energy of 88 kJ.

The reaction mechanism for the catalyzed decomposition of methanoic acid is:

Step 1: $HCOOH + H^{+} \longrightarrow HCOOH_2^{+}$ (Fast)

Step 2: $HCOOH_2^{+} \longrightarrow HCO^{+} + H_2O$ (Slow)

Step 3: $HCO^{+} \longrightarrow H^{+} + CO$ (Fast)



On a graph draw a potential energy diagram for the catalyzed decomposition of methanoic acid. Label the ΔH and the activation energy for this reaction.

8. The following equations represent a proposed mechanism for the decomposition of ozone, O_3, in the atmosphere.

Step 1: $Cl + O_3 \longrightarrow ClO + O_2$

Step 2: $CLO + O \longrightarrow Cl + O_2$

(a) Write the equation for the overall reaction. $O_3 + O \rightarrow 2O_2$

(b) Identify the catalyst. Cl

(c) Explain how a catalyst increases the rate of a reaction.

provides an alternate mechanism with a lower activation energy