Chemistry 12

Unit I: Reaction Kinetics Review Package

A1: demonstrate awareness that reactions occur at differing rates
A2: experimentally determine rate of a reaction

1. Which one of the following does **NOT** influence the rate of a chemical reaction involving only aqueous solutions?
   A. the pressure of the system
   B. the stability of the bonds
   C. the temperature of the system
   D. the number of reacting particles per litre

2. The following reaction occurs at **constant temperature and constant volume** in a closed system:

   $$CaCO_{3(s)} + 2H^{+}_{(aq)} + 2Cl^{-}_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$$

   Changes in which one of the following would be useful in experimentally measuring the rate of this reaction?
   A. The mass of the system
   B. The pressure of the system
   C. The concentration of water
   D. The concentration of $Cl^{-}_{(aq)}$

3. Which one of the following statements correctly describes the effect of catalysts on reaction rates?
   A. They have no effect on reaction rates
   B. they increase the rates of both the forward and reverse reactions
   C. They decrease the rate of the reverse reaction but no that of the forward reaction
   D. they increase the rate of the forward reaction but not that of the reverse reaction

4. Which one of the following reactions is **MOST** likely to have the highest rate at room temperature?
   A. $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$
   B. $Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg(OH)_{2(s)}$
   C. $C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$
   D. $2MnO_4^{-}{}_{(aq)} + 16H^{+}_{(aq)} + 5C_2O_4^{2-}{}_{(aq)} \rightarrow 2Mn^{2-}{}_{(aq)} + 10CO_{2(g)} + 8H_2O_{(g)}$

5. Given the following reaction: $2NaOCl_{(aq)} \rightarrow 2NaCl_{(aq)} + O_{2(g)}$

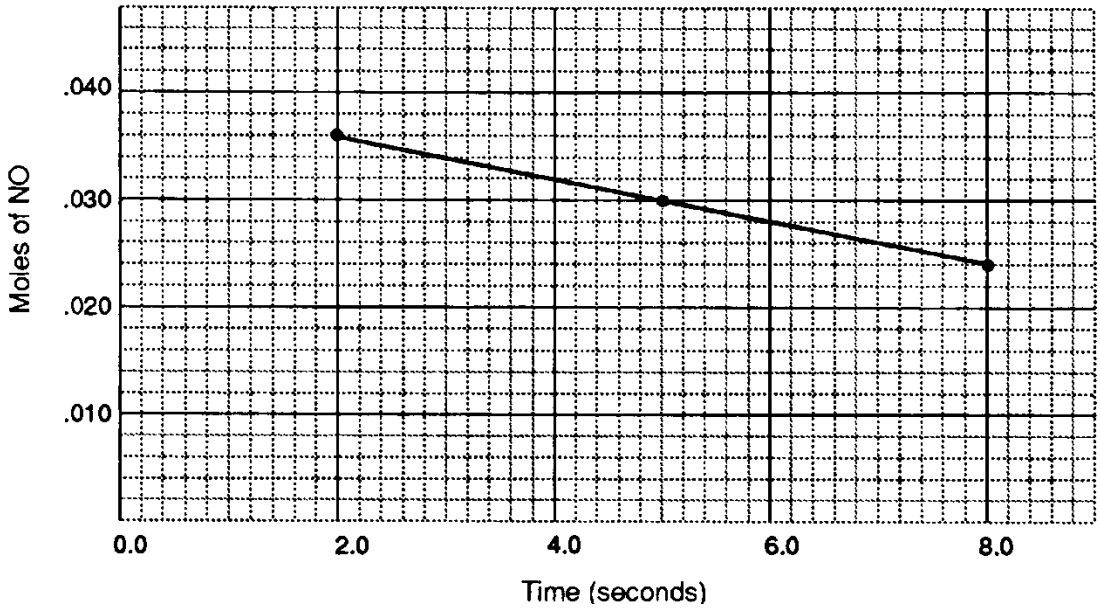
   The catalyst $Co_2O_{3(s)}$ is added to the above reaction and the system is closed. Which of the following properties could be monitored in order to determine reaction rate?
   A. Pressure
   B. Mass of Co_2O_3
   C. Concentration of Na^{+}
   D. Concentration of Co_2O_3

6. Consider the following reaction: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

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

7. Consider the following reaction: $2NO_{(g)} + 2H_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$

Data collected for the above reaction was used construct the following graph:



From the graph, the rate of this reaction in moles of NO consumed per second is:
A. 0.0020
B. 0.0030
C. 0.0060
D. 0.018

8. Consider the following reaction: $2N_2O_{5(g)} \rightarrow 4NO_{2(g)} + O_{2(g)}$

At a certain temperature the rate of decomposition of N_2O_5 is 2.5×10^{-6} mol/s. The rate of formation of NO_2 is:
A. 1.0×10^{-5} mol/s
B. 1.3×10^{-6} mol/s
C. 2.5×10^{-6} mol/s
D. 5.0×10^{-6} mol/s

9. Household bleach, NaClO, decomposes according to the following reaction:

$$2Na^{+}_{(aq)} + 2ClO^{-}_{(aq)} \rightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + O_{2(g)}$$

The rate of this reaction can be monitored by measuring the

A. decrease in $[Cl^{-}]$
B. increase in the $[Na^{+}]$
C. increase in the $[ClO^{-}]$
D. increase in volume of $O_{2(g)}$

10. Consider the following reaction: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$

Data collected for the above reaction are summarized in the table below:

Time (min)	**Mass of Zn (g)**	**Volume H_2 (mL)**	**Temperature (°C)**
0	4.65	0	20
2	4.50	50	21
4	4.35	100	22

The rate of this reaction can be measured in units of:

A. g/min
B. g/mL
C. min/mL
D. g/(mL)(°C)

11. Consider the following reaction: $NaOH_{(aq)} + HCl_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$
The rate of this reaction could be determined by monitoring the change in concentration of:

A. H^{+}
B. Cl^{-}
C. Na^{+}
D. H_2O

12. Consider the following reaction: $Zn_{(s} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

Solid zinc was added to 1.0 M HCl. In 20.0 s, the temperature of the container increased by 0.5°C and 25.00 mL of H_2 was produced. The rate of this reaction was

A. 0.5 °C/s
B. 1.0 M HCl/s
C. 1.25 mL H_2/s
D. 0.050 mol HCl/s

13. Which of the following reactions is **slowest** at room temperature?

A. $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$

B. $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

C. $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

D. $2Ag^{+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow Ag_2CO_{3(s)}$

14. Which of the following reactions occurs most rapidly at standard conditions?

A. $2Fe_{(s)} + O_{2(g)} \rightarrow FeO_{(s)}$

B. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)}$

C. $SnO_{2(s)} + 2CO_{(g)} \rightarrow Sn_{(s)} + 2CO_{2(g)}$

D. $2AgNO_{3(aq)} + Na_2CrO_{4(aq)} \rightarrow Ag_2CrO_{4(s)} + 2NaNO_{3(aq)}$

15. Consider the following reaction:

$$CaO_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)}$$

Which of the following could be used to measure the rate of this reaction?

A. change in acidity

B. change in volume

C. change in pressure

D. change in total mass

16. At 25ºC and considering <u>only</u> the nature of the reactants, which one of the following reactions most prbably has the highest rate?

A. $Ca^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3\,(s)}$

B. $CH_{4\,(g)} + 2\,O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\,H_2O_{\,(g)}$

C. $H_{2\,(g)} + I_{2\,(g)} \rightarrow 2\,HI_{\,(g)}$

D. $C_{\,(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$

17. Phosphorus ignites readily on exposure to air as below:

$$P_{4\,(s)} + 5\,O_{2\,(g)} \rightarrow P_4O_{10\,(s)} \quad \Delta H = -2980\ kJ/mol$$

At a given temperature, which of the following sets of factors determines the rate of the above reaction?

A. The partial pressure of the oxygen only.

B. The concentration of phosphorus and the volume of oxygen.

C.The concentration of phosphorus and the partial pressure of the oxygen.

D. The surface area of the phosphorus and the partial pressure of the oxygen.

18. A sample of magnesium having a mass of 0.360g is dropped into dilute hydrochloric acid. At the end of 4.00 minutes, the magnesium is removed and it is found to have a mass of 0.240g. The average rate at which the reaction took place was

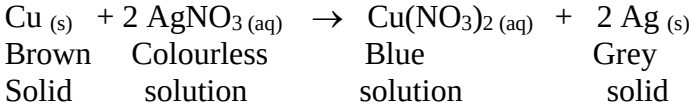
A. 0.003 mol/min

B. 0.120 mol/min

C.2.06×10^{-5} mol/sec

D. 8.33×10^{-5} mol/sec

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



Which of the following properties would BEST monitor the rate of this reaction?
A. concentration of the $NO_3^-{}_{(aq)}$
B. gas pressure
C. colour of the solution
D. mass of the system

20. For the reaction that follows, state two properties that might be monitored in order to determine the rate of the forward reaction.

21. A chemist wishes to determine the rate of reaction of magnesium with hydrochloric acid.
The equation for the reaction is: $Mg_{(s)} + 2H^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$
A piece of magnesium was dropped into 1.00 L of 0.100 M HCl and the following data were collected:

Time	Mass of Mg
0 s	0.012 g
2 s	0.010 g
4 s	0.008 g
6 s	0.006 g
8 s	0.004 g

a) Calculate the rate of reaction in terms of moles of Mg per second.
b) As this magnesium reacts with hydrochloric acid, does the pH increase or decrease? Support your answer with an explanation.

22. For the reaction that follows, state two properties that might be monitored in order to determine the rate of the forward reaction. $CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

23. The decomposition of N_2O_5 occurs according to the following equation: $2N_2O_5 \rightarrow 4NO_2 + O_2$

The following data are collected for the above reaction:

time (sec)	**mole N_2O_5**
START	1.62
2.00×10^2	1.46
4.00×10^2	1.30
6.00×10^2	1.14

Using the above data, calculate the reaction rate.

24. Consider the following reaction: $Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$

In a rate experiment, a coil of copper wire is placed into a solution of silver nitrate. The following data are recorded:

Time (hours)	Mass of Copper (g)
0.0	3.45
4.0	2.12

Calculate the rate of this reaction.

Answer Key

1. A
2. B
3. B
4. B
5. A
6. C
7. A
8. D
9. D
10. A
11. A
12. C
13. A
14. D
15. A
16. A
17. D
18. C
19. C

20. a) pH: As the reaction progresses, H^+ ions are used up and the $[H^+]$ decreases and pH increases.
b) Gas pressure: If the system is closed, the release of $CO_{2(g)}$ as the reaction proceeds would cause the pressure in the system to increase.

21. a) 4×10^{-5} mol/s
b) pH increases because some H^+ ions are used up in the reaction therefore the $[H^+]$ decreases increasing the pH.

22. pressure of system (if closed), pH, mass of system (if open), $[Ca^{2+}]$

23. Rate = 0.00080 mol N_2O_5/second **or** 0.048 mol N_2O_5/min

24. Δmass Cu $= 2.12g - 3.45g = -1.33$ g $\qquad \Delta t = 4.0$ h

rate $= -1.33g/4.0$ h $= 0.33$ g/h **or** 5.5×10^{-3} g/min **or** 9.2×10^{-5}g/s

A3: demonstrate knowledge of collision theory
A5: apply collision theory to explain how reaction rates can be changed

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

26. 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

27. 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

28. Consider the following reaction: $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} + 112\ kJ$

    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

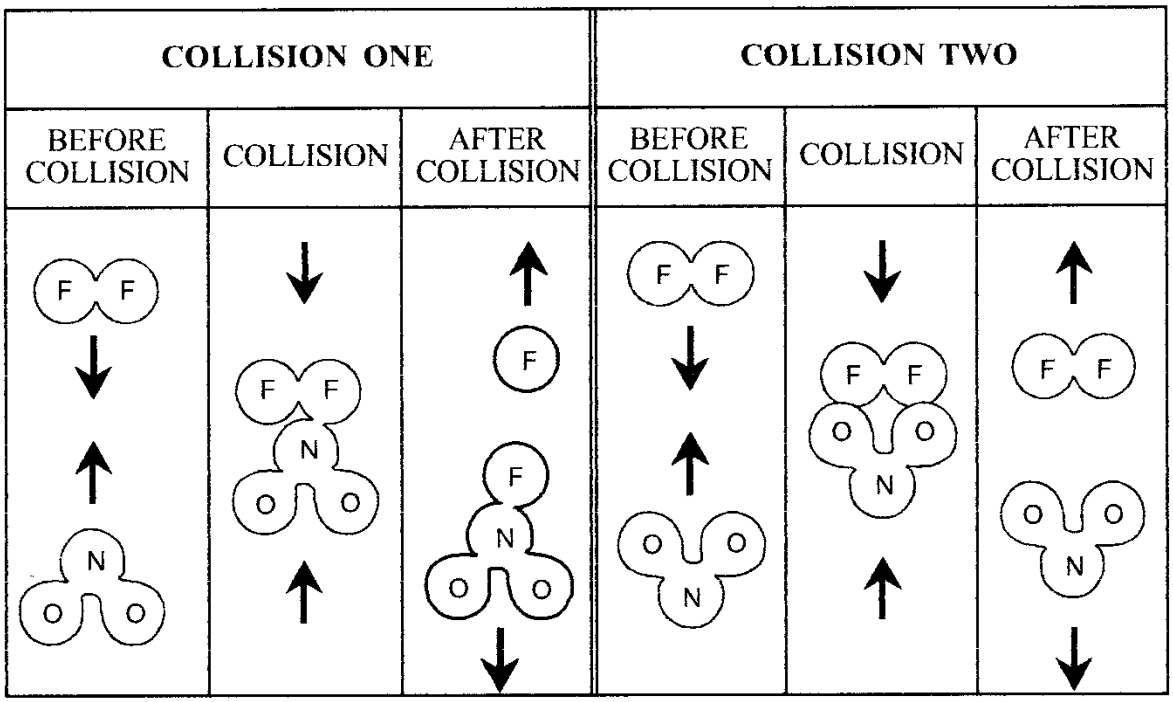
29. Consider the following equation: $2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$

    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

30. Hydrogen peroxide decomposes to produce water and oxygen. $2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$ The rate of this reaction can be increased by the addition of manganese (IV) oxide. In this reaction manganese (IV) oxide is acting as:
    A. a catalyst
    B. an inhibitor
    C. an activated complex
    D. a reaction intermediate

31. Consider the following reaction: $2S_{(s)} + 3O_{2(g)} \rightarrow 2SO_{3(g)} + \text{heat}$
The rate of this reaction could be increased by:
A. decreasing temperature
B. adding a catalyst
C. increasing the concentration of $S_{(s)}$
D. increasing the concentration of $SO_{3(g)}$

32. Consider the following collisions, each occurring at the same temperature:



Which one of the following factors explains why collision one is successful while collision two is not successful?
A. Catalyst
B. Geometry
C. Concentration
D. Kinetic energy

33. Consider the following reaction: $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

As the temperature of the above system is increased, the number of collisions:
A. increases but fewer are effective.
B. decreases and fewer are effective.
C. increases and more are effective.
D. decreases but more are effective.

34. Milk is refrigerated in order to slow the rate of decomposition by bacterial action. The decrease in reaction rate is due to:
A. a decrease in surface area
B. a decrease in ΔH for the reaction
C. a decrease in the fraction of particles possessing sufficient energy
D. the introduction of an alternate pathway with greater activation energy

35. An untreated sugar cube does not burn when held over a lighted match. A sugar cube coated with cigarette ash readily ignites and burns. All of the cigarette ash remains after the reaction. The **factor** that caused this change in rate is the:
A. nature of reactants.
B. presence of a catalyst.
C. increase in surface area.
D. increase in concentration

36. In order for a collision between reactant particles to be successful:
A. ΔH must be positive
B. the system must be closed
C. there must be sufficient KE
D. the change in KE must be less than the change in PE

37. Consider the following reaction: $BaCO_{3(s)} + 2H^{+}_{(aq)} \rightarrow Ba^{2+}_{(aq)} + H_2O_{(l)} + CO_{2(g)} + \text{heat}$

A change that would **decrease** the rate of formation of $CO_{2(g)}$ is:

A. finely powder the $BaCO_{3(s)}$
B. decrease the temperature of the system
C. add water to the system
D. increase the concentration of $H^{+}_{(aq)}$

38. Which of the following are necessary for successful collisions to occur?
I Favorable collision geometry
II Sufficient Kinetic energy
III Large ΔH

A. I only
B. I and II only
C. II and III only
D. I, II, and III

39. Collision theory states that:
A. All collisions lead to chemical reactions
B. Most collisions lead to chemical reactions
C. Very few reactions involve particle collisions
D. Effective collisions lead to chemical reactions

40. In a chemical reaction, which of the following is not true?
A. most collisions are successful
B. successful collisions have favourable geometry
C. successful collisions have sufficient energy
D. a collision is required

41. As reactant molecules approach each other
A. Heat is released
B. A reaction intermediate forms
C. Kinetic energy changes to potential energy
D. Potential energy changes to kinetic

42. Consider the following reaction:

$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

As a molecule of H_2 approaches a molecule of Cl_2 on a collision course, how do the KE and PE change?

	KE	PE
A.	increases	decreases
B.	decreases	increases
C.	decreases	decreases
D.	increases	increases

43. Consider the reaction: $2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$
Which of the following explains, in terms of collision theory, why this reaction occurs in more than one step?
A. a low $C_4H_{12(g)}$ pressure
B. low temperature of reactant mixture
C. low probability of a multi-particle collision
D. particles collide with insufficient kinetic energy

44. Given the following reaction, which one of the following changes would <u>increase</u> the rate of evolution of CO_2?

$CaCO_{3(s)} + 2H^+_{(aq)} \rightarrow Ca^{2+}_{(aq)} + H_2O + CO_{2\,(g)} + \text{heat}$

A. Decrease the temperature of the system
B. Increase the concentration of $Ca^{2+}_{(aq).}$
C. Finely powder the $CaCO_3$ (s).
D. Add water to the system.

45. Which one of the following is the basic premise expressed in Collision Theory?
A. Chemical reactions can occur only if reacting particles collide.
B. At a high temperature, more gas particles collide than at low temperature.
C. In order to react, particles must have the correct geometry when they collide
D. Catalysts affect the rate at which reacting particles collide.

46. Which of the following factors affects the rate of heterogeneous reactions only?
A. Presence of a catalyst
B. The pressure of the system
C. Concentration of reactants
D. Surface area of reactants

47. Coal dust is found to burn more rapidly than a lump of coal. The FACTOR that increases the rate of the chemical reaction is the.
A. Presence of a Catalyst.
B. Surface area of the reactants.
C. Concentration of the reactants.
D. Chemical properties of the reactants.

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

$$PCl_{5\,(g)} \rightarrow PCl_{3\,(g)} + Cl_2$$

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

49. For the reaction, $Zn_{(s)} + S_{(g)} \rightarrow ZnS_{(s)}$ $\Delta H = -460kJ$, which of the following would increase the rate of the reaction?
A. Change $Zn_{(s)}$ to a fine powder.
B. Decrease the pressure.
C. Decrease the temperature.
D. Remove $ZnS_{(s)}$ as it is formed.

50. When the temperature of a gaseous mixture is increased from 10^oC to 20^oC, it is found that the reaction rate doubles. Which of the following could be deduced from this information?
A. At the higher temperature all collisions lead to reaction.
B. The average kinetic energy has been doubled by raising the temperature.
C. The frequency of effective collisions has been doubled.
D. The activation energy has been reduced by raising the temperature.

51. Consider the following reaction:

$$CaCO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow CO_{2\,(g)} + CaCl_{2\,(aq)} + H_2O_{(l)} + \text{Heat}$$

In which of the following will BOTH of the described procedures cause an increase in the rate at which products are formed?
A. Increase [HCl] and decrease in pressure
B. Increase [HCl] and increase temperature
C. Increase [HCl] and decrease temperature
D.Grind up the $CaCO_3$ and decrease temperature

52. Equal volumes of $I^-_{(aq)}$ and $H_2O_{2(aq)}$ solutions were individually reacted with 0.10 M $Cr_2O_7^{-2}{}_{(aq)}$ and the following data were obtained:

Reactant	Concentration	Temperature	Time for reaction
I^{-1}	0.10 M	20^OC	1.5 s
H_2O_2	0.20 M	30^OC	12 s

The factor that accounts for the shorter reaction time for I^{-1} is:
A. temperature
B. surface area
C. concentration
D. nature of reactants

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

$$Br_{2(g)} + Cl_{(2)} \rightarrow 2\ BrCl_{(g)} \qquad \Delta H = -61\ KJ$$

Which change will increase the frequency of effective collisions between Br_2 and Cl_2 molecules?
A. remove some $BrCl_{(g)}$
B. decrease the pressure
C. Increase the temperature
D. increase the container volume

54. 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 zinc, 50^OC
B. 1.0 M H_2SO_4, powdered zinc, 50^OC
C. 1.0 M H_2SO_4, block of zinc, 50^OC
D. 1.0 M H_2SO_4, powdered zinc, 25^OC

55. Describe TWO ways of increasing the **rate** of the following reaction, other than by using a catalyst, and explain in terms of molecular behavior why each method would be successful.

$$2\ NOCl_{(g)} \rightarrow 2\ NO_{(g)} + Cl_{2\,(g)} \quad \Delta H = -56\ kJ$$

56. When a burning match is touched to the wick of a candle, the reaction between the candle wax and oxygen begins. When the match is removed, the candle continues to burn. Explain why the match is required to initiate the reaction, but is not needed once the reaction has started.

57. List two requirements for an effective collision between two reactant molecules.

58. Air is mainly a mixture of nitrogen and oxygen molecules. These molecules can react to produce nitrogen dioxide, a red-brown gas: $N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$

Even though there are more than four billion collisions per second between N_2 and O_2, the amount to nitrogen dioxide present after a year is too small to be detected. Using the collision theory, give **TWO** reasons why this reaction is so slow.

59. Carbon burns in air according to the following equation: $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$
List **four** ways the rate of the above reaction could be increased.

Answers

25. B	35. B	45. A
26. D	36. C	46. D
27. D	37. B	47. B
28. A	38. B	48. A
29. A	39. D	49. A
30. A	40. A	50. C
31. B	41. C	51. B
32. B	42. B	52. D
33. C	43. C	53. C
34. C	44. C	54. B

55. a) Increasing the temperature would cause the rate of the reaction to increase because the molecules that are colliding would collide at a greater rate (more often). This would happen because of the extra speed at which the molecules would be travelling due to the increase in energy inputted into the system.
b) Increasing the pressure of the system would allow the molecules that are reacting to collide more frequently therefore the reaction rate would increase. NOTE : By increasing both of the above, the position of the equilibrium would also change and the result may be actually favouring the reactants but this shift in position was not asked for in the question.

56. The burning match is required to give the reactants sufficient kinetic energy to...

...react **or** collide effectively **or** overcome E_a

The reaction is exothermic and is able to supply the KE after the reaction is started.

57. Sufficient kinetic energy (to overcome E_a) and Favourable (or optimum) collision geometry.

58. Reason #1: The reaction likely has a high activation energy making it unlikely that a collision will have sufficient kinetic energy to overcome the Ea.
Reason #2: Because there are 3 reactant particles and the probability that all 3 particles will collide with the correct geometry is miniscule.

59. - increase $[O_2]$ (or partial pressure O_2)
- grind up C (or increase SA of C)
- add a catalyst
- increase temperature

A4: describe the energies associated with reactants becoming products

60. Select the equation that represents an exothermic reaction.

A. $\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow NO_{(g)} \qquad \Delta H = 90.29$ kJ/mol

B. $\frac{1}{2}N_{2(g)} + O_{2(g)} + 33.81\text{ kJ} \rightarrow NO_{2(g)}$

C. $\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2(g)} \rightarrow NH_{3(g)} + 46.15\text{ kJ}$

D. $\frac{1}{2}N_{2(g)} + \frac{5}{2}O_{2(g)} + \text{energy} \rightarrow N_2O_{5(g)}$

61. A positive sign for H in a chemical reaction indicates that:

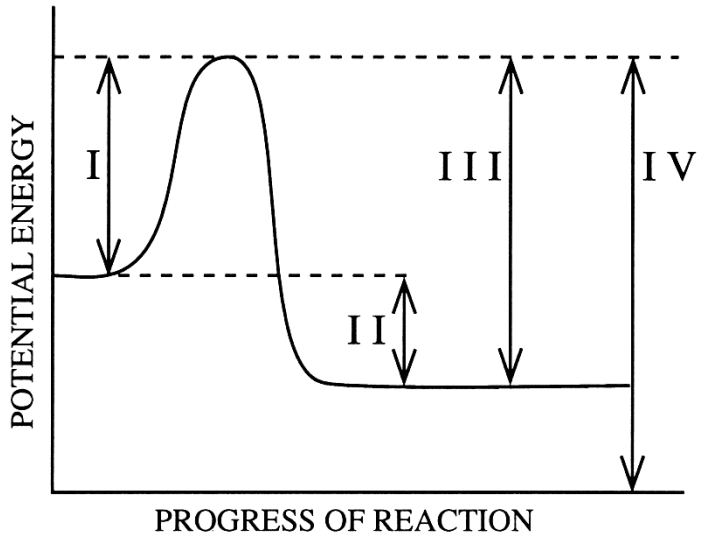
A. the reaction will occur spontaneously
B. the reactants have less potential energy than the products
C. the reaction is exothermic
D. the products have less potential energy than the reactants

62. Select the equation that represents an endothermic reaction:

A. $C_{(graphite)} + 1.88\text{ kJ} \rightarrow C_{(diamond)}$
B. $C_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{(g)} + 110.4\text{ kJ}$
C. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = -393.5$ kJ/mol
D. $C_{(s)} + 2H_{2(g)} \rightarrow CH_{4(g)} + \text{energy}$

63. In the following PE diagram, select the interval that represents the change in enthalpy.

A. I
B. II
C. III
D. IV



64. Which one of the following changes accompanies an endothermic reaction?

A. The mass of the products is less than that of the reactants.
B. The mass of the products is larger than that of the reactants.
C. The potential energy of the products is less than that of the reactants.
D. The potential energy of the products is greater than that of the reactants.

65. Which of the following equations represents an endothermic reaction?

A. $2BrCl_{(g)} - 29.3\ kJ \rightarrow Br_{2(g)} + Cl_{2(g)}$

B. $CaO_{(s)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + 178\ kJ$

C. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)} \qquad \Delta H = +13.4\ kJ$

D. $H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{g)} \qquad \Delta H = -241\ kJ$

66. Which of the following reactions is endothermic?

A. $H_{2(g)} + S_{(s)} \rightarrow H_2S_{(g)} + 20\ kJ$

B. $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)} \qquad \Delta H = -296\ kJ$

C. $6C_{(s)} + 3H_{2(g)} \rightarrow C_6H_{6(l)} \qquad \Delta H = +83\ kJ$

D. $C_{(s)} + 2H_{2(g)} + \frac{1}{2}O_{2(g)} - 201\ kJ \rightarrow CH_3OH_{(g)}$

67. 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.

68. Consider the potential energy diagram below:

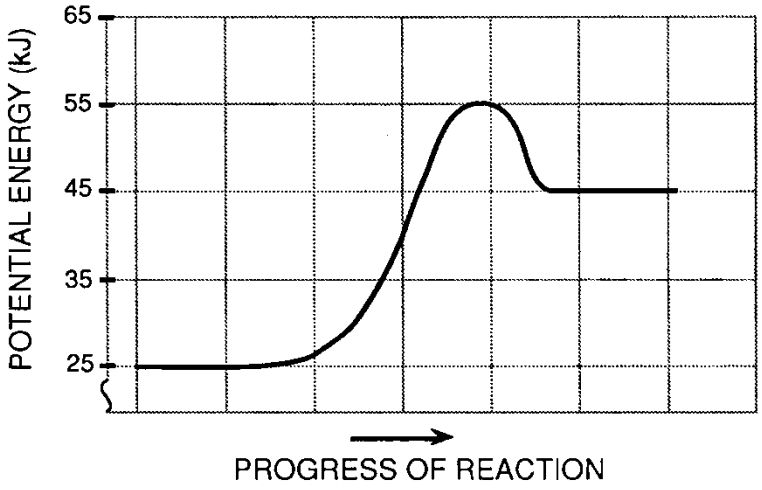
The value of the activation energy (E) for the forward reaction is:

A. 10 kJ

B. 20 kJ

C. 30 kJ

D. 55 kJ



69. Consider the following reaction: $2NO_{(g)} + O_{2(g)} \rightarrow NO_{2(g)} + 114\ kJ$

The reaction is:

A. exothermic and ΔH is positive

B. exothermic and ΔH is negative

C. endothermic and ΔH is positive

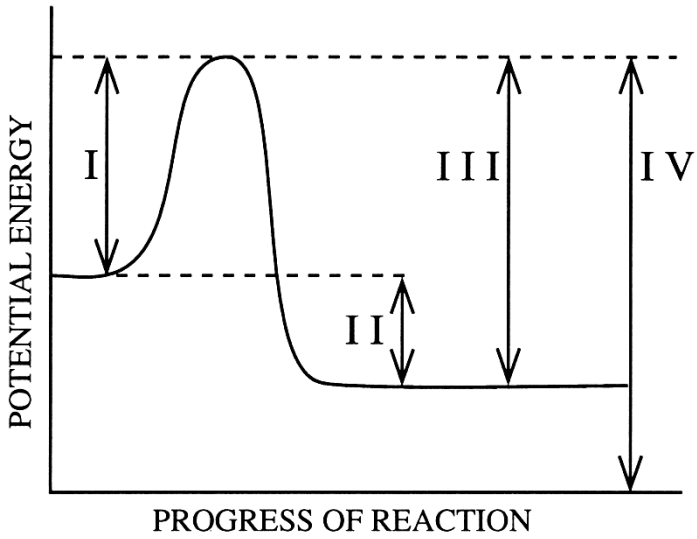
D. endothermic and ΔH is negative

70. Consider the following reaction: $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} + 112\ kJ$

The ΔH for the above reaction is:

A. positive and the reaction is exothermic
B. negative and the reaction is exothermic
C. positive and the reaction is endothermic
D. negative and the reaction is endothermic

71. Consider the following potential energy diagram:



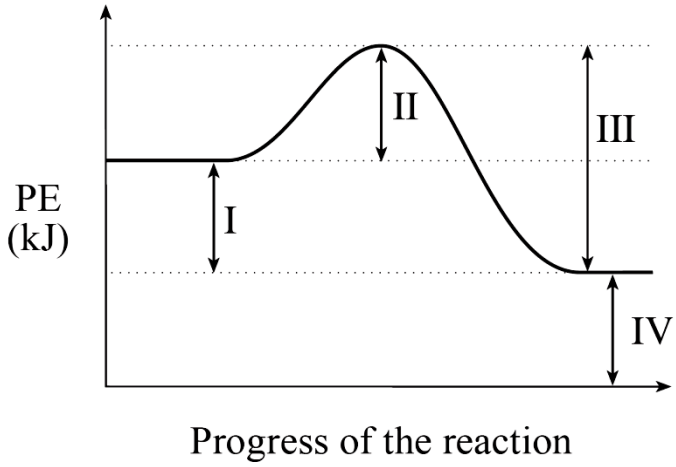
The energy interval that represents the activation energy for the **reverse** reaction is:

A. I
B. II
C. III
D. IV

72. Consider the following PE diagram:

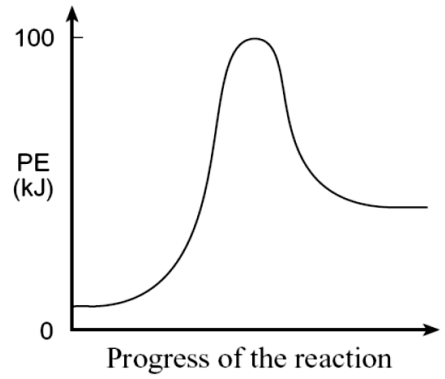
The activation energy for the forward reaction is represented by:

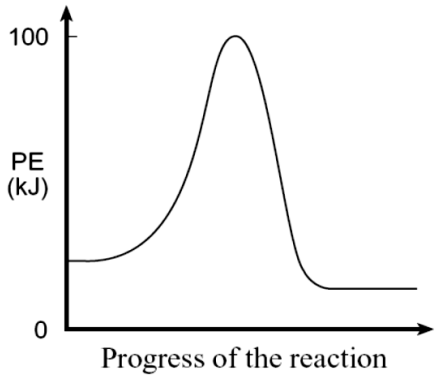
A. I
B. II
C. III
D. IV

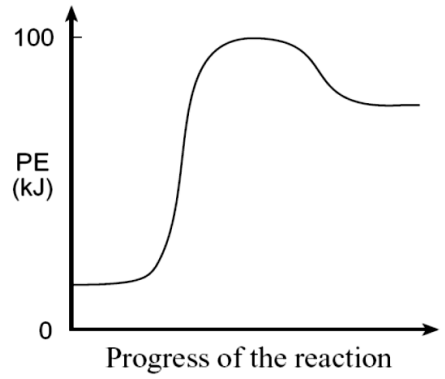


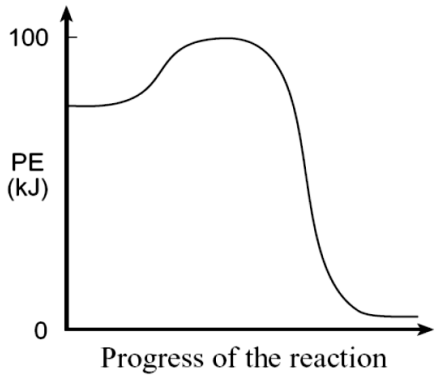
73. What is the relationship between the activation energy and the rate of a reaction?
A. When the activation energy is high, the rate of reaction is fast.
B. When the activation energy is low, the rate of reaction is slow.
C. When the activation energy is high, the rate of reaction is slow.
D. There is no relationship between activation energy and rate of reaction.

74. Which of the following corresponds to the fastest reaction at room temperature?

A.


B.


C.


D.


75. In general, a chemical reaction requiring a large activation energy will proceed
A. At a fast rate
B. At a slow rate
C. Only at a low temperature
D. Only at low concentrations

76. Consider the following reaction:

$CH_4 + Cl_2 \rightarrow CH_2Cl_2 + H_2$

Which answer best describes the activated complex?

	Formula	KE relative to reactants
A.	CH_4	higher
B.	CH_4	lower
C.	CH_4Cl_2	higher
D.	CH_4Cl_2	lower

77. What happens to the activation energy as the temperature in a reacting system decreases?
A. the activation energy increases
B. the activation energy decreases
C. the activation energy stays the same
D. the activation energy is converted to kinetic energy

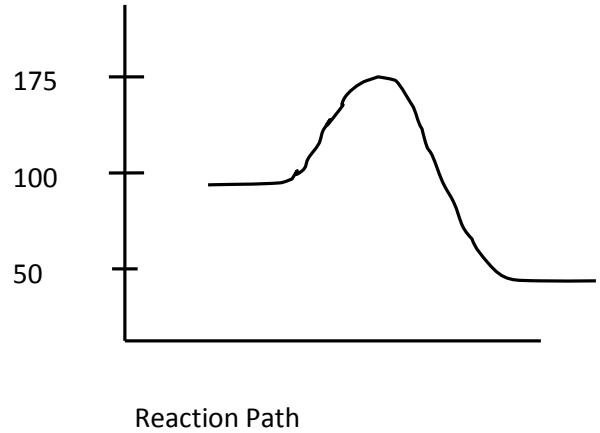
78. Consider the following reaction:

$\frac{1}{2} N_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow NO_{(g)}$ $\Delta H = +90$ kJ/mol NO

The correct equation including the heat term is

A. $N_{2(g)} + O_{2(g)} + 90$ kJ $\rightarrow 2NO_{(g)}$
B. $N_{2(g)} + O_{2(g)} + 180$ kJ $\rightarrow 2NO_{(g)}$
C. $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)} + 90$kJ
D. $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)} + 180$kJ

79. Consider the following potential energy diagram



The Activation energy for the forward reaction is
A. 25 kJ
B. 50 kJ
C. 75 kJ
D. 125 kJ

80. Consider the following reaction:
$\frac{1}{2} H_{2(g)} + \frac{1}{2} I_{2(g)} \rightarrow HI_{(g)}$

The activation energy for the formation of HI is 167 kJ and for the decomposition of HI is 139 kJ. The reaction for the formation of HI is

A. Exothermic and the $\Delta H = -28$ kJ
B. Exothermic and the $\Delta H = +28$ kJ
C. Endothermic and the $\Delta H = -28$ kJ
D. Endothermic and the $\Delta H = +28$ kJ

81. Which of the following equations represents an endothermic reaction?
A. $N_20_{4(g)} + 59$ kJ $\rightarrow 2NO_{2(g)}$
B. $2H_{2(g)} + 0_{2(g)} \rightarrow 2H_2O_{(l)} + 572$ kJ
C. $2BrCl_{(g)} - 29.3$ kJ $\rightarrow Br_{2(g)} + Cl_{2(g)}$
D. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -394$ kJ

82. Consider the following reaction:

$\frac{1}{2} H_{2(g)} + \frac{1}{2} I_{2(g)} \rightarrow HI_{(g)} \quad \Delta H = +28$ kJ

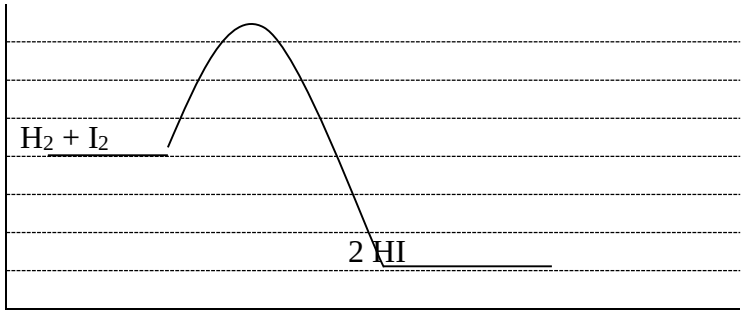
The activation energy for the formation of HI is 167 kJ. The activation energy for the decomposition of HI (the reverse reaction) is:

A. 28 kJ
B. 139 kJ
C. 167 kJ
D. 195 kJ

83. Which of the following represent an endothermic reaction?

A. $H_{2(g)} \rightarrow 2H_{(g)} \quad \Delta H = 436$ kJ/mol
B. $\frac{1}{2} H_{2(g)} + \frac{1}{2} Br_{2(l)} \rightarrow HBr_{(g)} \quad \Delta H = -36.23$kJ/mol
C. $\frac{1}{2} H_{2(g)} + \frac{1}{2} Cl_{2(g)} \rightarrow HCl_{(g)} +$ heat
D. $H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(g)} +$ 241.8 kJ

84. For the reaction depicted by the potential energy diagram, which one of the following statements is true about the rate of the reaction?

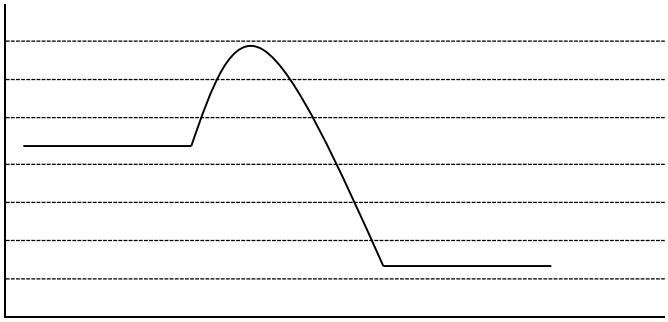


A. depends on the concentration of the reactants and upon the temperature.
B. It depends upon the concentration of the reactants but is temperature independent.
C. It depends upon the temperature but is independent of the concentration.
D. It is independent of both the concentration of the reactants and the temperature.

85. Which of the following statements best describes the <u>enthalpy</u> change (ΔH) of a reaction?

A. ΔH is the maximum amount of useful work obtainable from a reaction at a given temperature.
B. ΔH measures the change in randomness of a reaction taking place at a constant temperature.
C. ΔH is equal to the energy required to initiate a chemical reaction under given conditions
D. ΔH is equal to the change in energy content of the system at a constant temperature and pressure.

86. Which of the following can be inferred from the graph below?



A. The reverse reaction is endothermic.
B. The reaction mechanism has two elementary processes.
C. The energy of activation of the forward reaction is greater than that of the reverse reaction.
D. As the temperature increases, the rate of the forward reaction increases more than the rate of the reverse reaction.

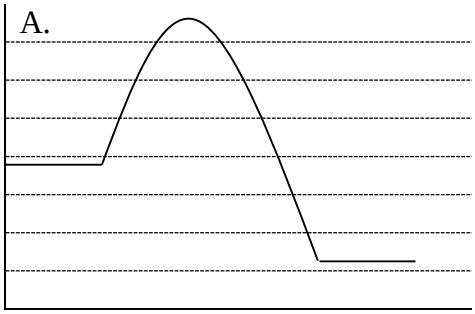
87. Which one of the following statements is TRUE about the activated complex in a reaction?
A. it acts as a catalyst.
B. it is a stable compound
C. it always forms products
D. it possesses more energy than the reactants or the products

88. Consider the following SLOW reaction:

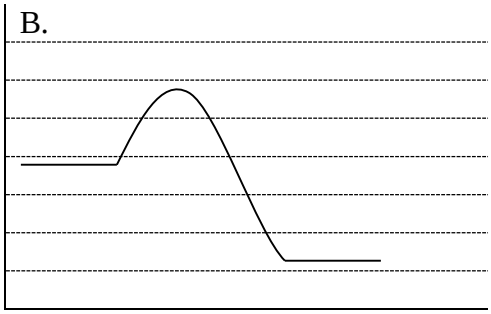
$$CO_{(g)} + NO_{2\,(g)} \rightarrow CO_{2\,(g)} + NO_{(g)} + \text{heat}$$

Which of the following potential energy diagrams BEST represents the above reaction

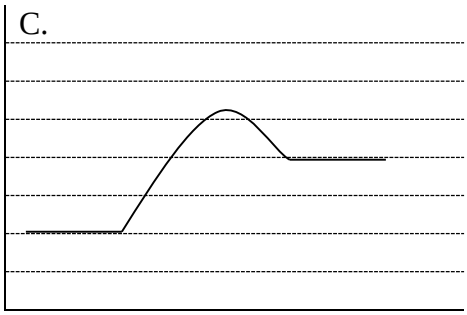
A.



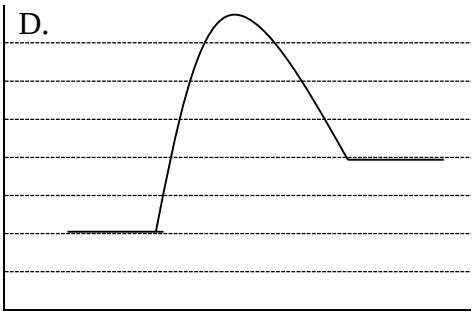
B.



C.



D.



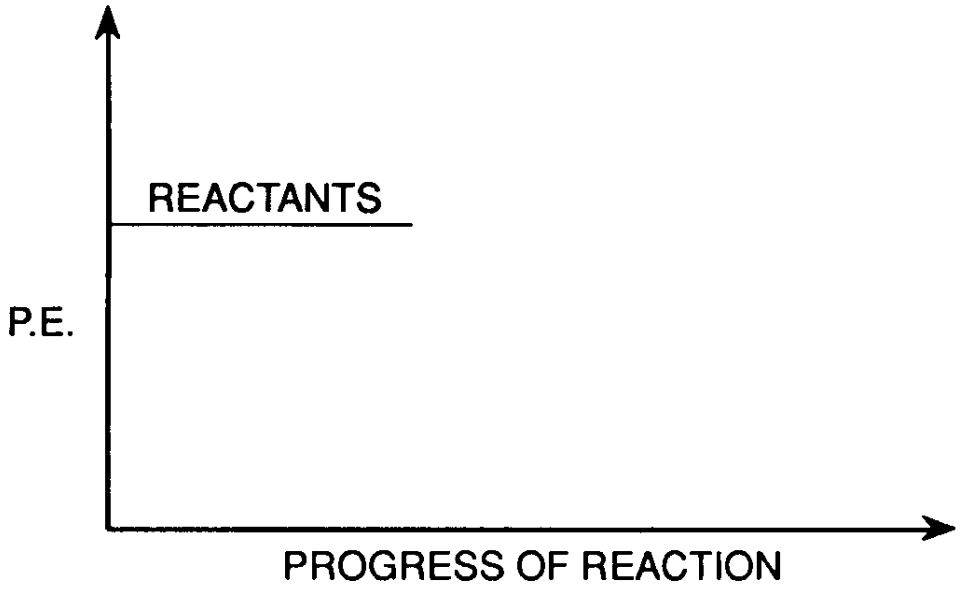
89. An activated complex may be described as a molecular species which is
A. long lived and has low PE
B. short lived and has low PE
C. short lived and has high PE
D. long lived and has high PE

90. Describe what happens to the kinetic energy, the potential energy, and the total energy of reactant molecules as they approach one another.

91. Explain why a lower activation energy leads to a greater reaction rate at a given temperature.

92. Define the term "activation energy" **.**

93. Complete the following potential energy (PE) diagram for an exothermic reaction. Label activation energy (E) and ΔH.



Answers:

60. C
61. B
62. A
63. B
64. D
65. C
66. C
67. B
68. C
69. B
70. B
71. C
72. B
73. C
74. D
75. B
76. D
77. C
78. B
79. C
80. D
81. A
82. B
83. A
84. A
85. D
86. A
87. D
88. A
89. C

90. Kinetic energy of molecules decreases as the molecules approach each other. Potential energy of molecules increases as the molecules approach each other. The total amount of energy of reactant molecules remains constant.

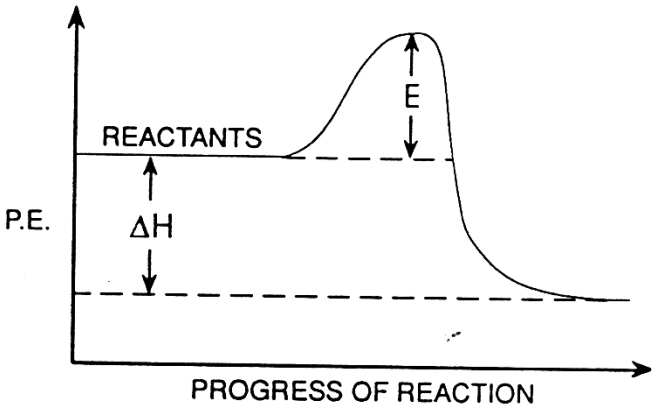
91. A lower activation energy means that reactant molecules need less kinetic energy in order to react, therefore, at a given temperature, a greater number of reactant molecules will possess the necessary kinetic energy, thus a greater reaction rate results.

92. The minimum change in potential energy of the reactants required to initiate a reaction
or to have effective collisions
or to achieve the activated complex

OR

The minimum kinetic energy of the reactants required to initiate a reaction
or to have effective collisions
or to achieve the activated complex

93.



1 mark for correct PE diagram
$\frac{1}{2}$ mark for Δ H interval
$\frac{1}{2}$ mark for E interval

A6: analyse the reaction mechanism for a reacting system
A7: represent graphically the energy changes associated with catalyzed and uncatalyzed reactions
A8: describe the uses of specific catalysts in a variety of situations

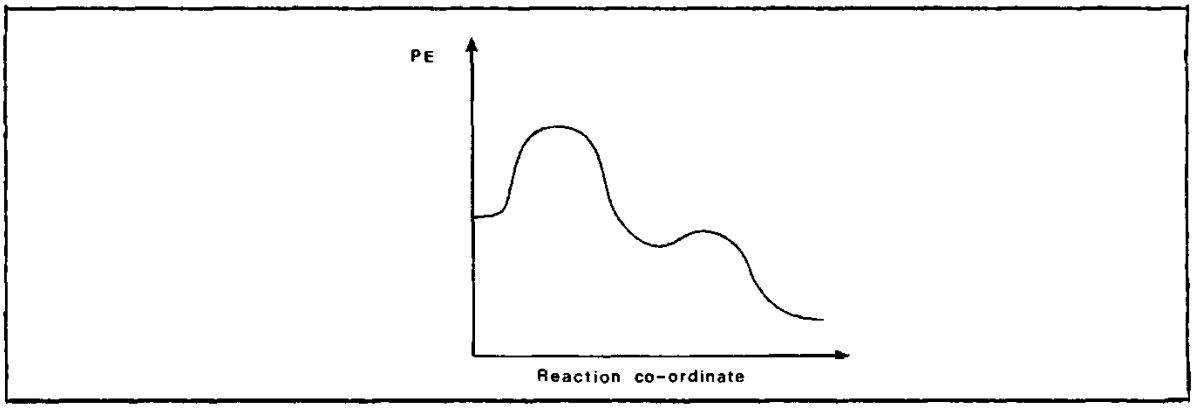
94. Which one of the following describes one effect of a catalyst?
A. it increases the total energy of the products
B. it decreases the energy released in a reaction
C. it proves a new mechanism for the reaction involving a lower activation energy
D. it speeds up the rate of reaction but is used up in the overall process

95. Which one of the following statements is **TRUE** about what occurs after a catalyst has been added to a system?.
A. The forward rate only will increase.
B. The reverse rate only will increase.
C. The forward and reverse reaction rates will both increase.
D. The forward and reverse reaction rates will both remain unchanged

96. Which one of the following terms refers to the slowest step in a reaction mechanism?
A. Uncatalyzed
B. Rate-determining
C. Activated complex
D. Activation energy

97. When a lit match is touched to the wick of a candle, the candle begins to burn. When the match is removed, the candle continues to burn. In this reaction, the match
A. behaves as a catalyst
B. supplies activation energy
C. is part of the rate determining step
D. lowers the activation energy barrier

Use the following graph to answer question 98.



98. The above potential energy graph represents a reaction which **MUST**
A. involve a catalyst.
B. have a slow rate once initiated.
C. be endothermic in the forward direction.
D. have two steps in its reaction mechanism.

99. Consider the following two-step reaction mechanism:

Step 1: $NO_2 + SO_2 \rightarrow SO_3 + NO$

Step 2: $NO + \frac{1}{2} O_2 \rightarrow NO_2$

The net reaction is:

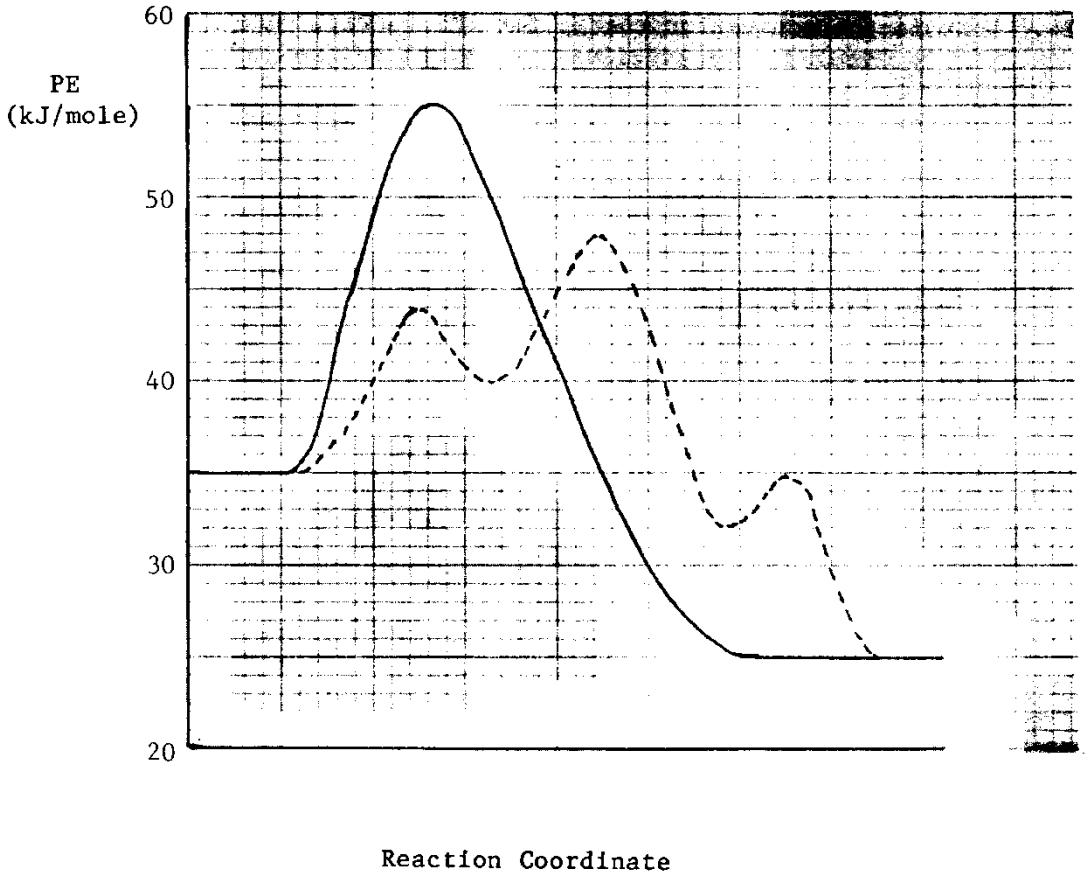
A. $SO_2 + \frac{1}{2} O_2 \rightarrow SO_3$

B. $SO_2 + \frac{1}{2} O_2 + NO \rightarrow SO_3 + NO$

C. $SO_2 + \frac{1}{2} O_2 + NO_2 \rightarrow SO_3 + NO_2$

D. $SO_2 + \frac{1}{2} O_2 + NO_2 + NO \rightarrow SO_3 + NO_2 + NO$

Use the potential energy graph below to answer questions 100 – 102. The solid line represents the uncatalyzed reaction mechanism; the dotted line represents the catalyzed reaction mechanism.



64.

What is ΔH for the catalyzed reaction?

A. –23 kJ

B. –10 kJ

C. +10 kJ

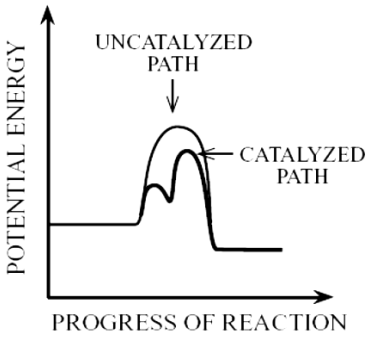
D. +48 kJ

101. What is the activation energy for the forward uncatalyzed reaction?
A. –20 kJ
B. +20 kJ
C. +30 kJ
D. +55 kJ

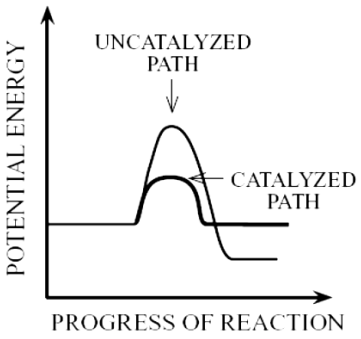
102. What is the activation energy for the reverse catalyzed reaction?
A. +19 kJ
B. +23 kJ
C. +30 kJ
D. +48 kJ

103. An uncatalyzed reaction was found to produce 40 kJ of energy in 10 minutes. When catalyzed, the same reaction produced 40 kJ of energy in 2 minutes. Which one of the following potential energy diagrams is consistent with the above data?

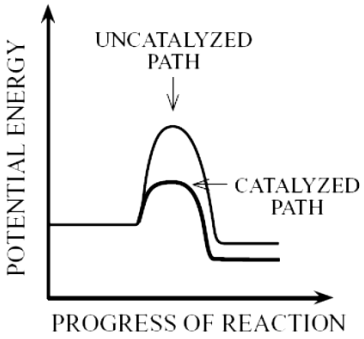
A.



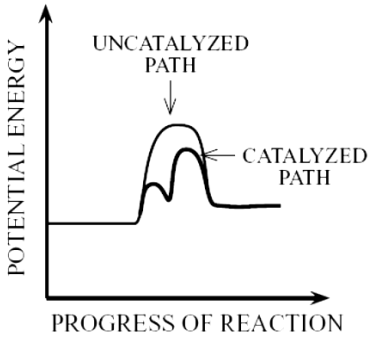
B.



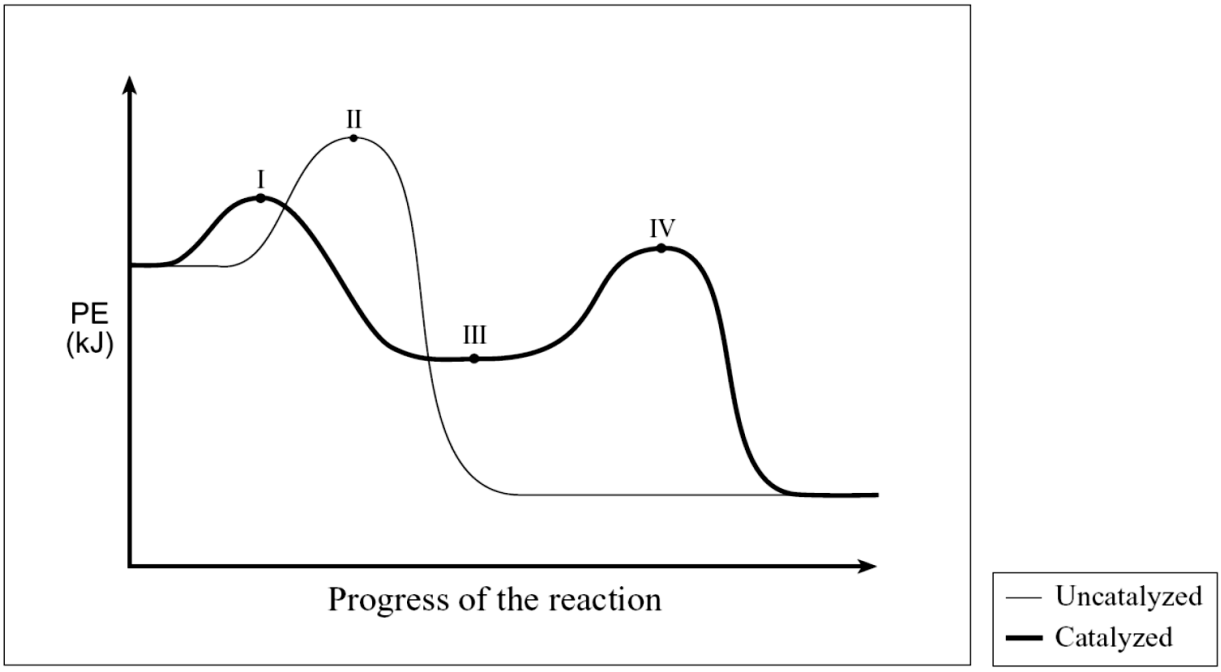
C.



D.



Use the following diagram to answer numbers 104. and 105.



104. Select the **true** statement concerning the above potential energy diagram.
   A. The catalyzed reaction has a larger ΔH.
   B. The uncatalyzed reaction has a larger ΔH.
   C. The catalyzed reaction has a greater rate of reaction.
   D. The uncatalyzed reaction has a greater rate of reaction.

105. Which point on the diagram above represents the potential energy of the activated complex formed in the uncatalyzed reaction?
   A. I
   B. II
   C. III
   D. IV

106. A catalyst increases the rate of a reaction by
   A. Increasing the concentration of the reactant(s)
   B. Decreasing the concentration of the reactant(s)
   C. Increasing the activation energy of the overall reaction
   D. Decreasing the activation energy of the overall reaction

107. Which of the following would change the value of the activation energy for a heterogeneous reaction?
   A. adding a catalyst
   B. changing the surface area
   C. changing the reactant concentration
   D. changing the average kinetic energy

108. A catalyst increases the rate of a reaction by
A. Increasing the concentration of the reactant(s)
B. Decreasing the concentration of the reactant(s)
C. Increasing the activation energy of the overall reaction
D. Decreasing the activation energy of the overall reaction

109. When a catalyst is added to a reaction, ΔH will
A. Increase slowly
B. Remain constant
C. Decrease slowly
D. Increase rapidly due to alternate pathway

110. The activated complex is best described as:

A.	stable	maximum PE	minimum KE
B.	stable	minimum PE	maximum KE
C.	unstable	maximum PE	minimum KE
D.	unstable	minimum PE	maximum KE

111. Consider the following reaction mechanism

Step 1: $M + X \rightarrow MX$
Step 2: $MX + A \rightarrow D + X$

The chemical species MX is a(n)
A. Catalyst
B. Inhibitor
C. Final Product
D. Reaction Intermediate

112. Consider the following reaction mechanism

Step 1: $NO_2 + NO_2 \rightarrow NO + NO_3$

Step 2: $NO_3 + CO \rightarrow NO_2 + CO_2$

The overall reaction is

A. $2NO_2 \rightarrow NO_3 + NO$
B. $NO_2 + CO \rightarrow NO + CO_2$
C. $NO_3 + CO \rightarrow NO_2 + CO_2$
D. $NO_2 + NO_3 + CO \rightarrow NO_3 + NO_2 + NO + CO_2$

113. Consider the following reaction mechanism

Step 1: $NO_{2(g)} + NO_{2(g)} \rightarrow NO_{(g)} + NO_{3(g)}$ (slow)
Step 2: $NO_{3(g)} + CO_{(g)} \rightarrow CO_{2(g)} + NO_{2(g)}$ (fast)

Which one of the following changes would result in the greatest increase in reaction rate
A. Increase [CO]
B. Decrease [NO]
C. Increase [NO_2]
D. Increase [NO_3]

114. Consider the following reaction mechanism

Step 1: $ICl + H_2 \rightarrow HI + HCl$ (slow)
Step 2: $ICl + HI \rightarrow HCl + I_2$ (fast)

The Species HCl is a
A. Product
B. Catalyst
C. Reactant
D. Reaction Intermediate

115. In a reaction mechanism, the rate determining step is the
A. Fastest and has the lowest reaction rate.
B. Fastest and has the highest activation energy
C. Slowest and has the lowest activation energy
D. Slowest and has the highest activation energy

116. Consider the following reaction
Step 1: $NO_{(g)} + O_{3(g)}$ ------ > $NO_{2(g)} + O_{2(g)}$
Step 2: $O_{(g)} + NO_{2(g)}$ ------ > $NO_{(g)} + O_{2(g)}$
The catalyst is
A. O_2
B. O_3
C. NO
D. NO_2

117. Define activated complex.

118. Explain why the mechanism for the reaction below would probably involve more than the single step implied by the equation.

$$2\ NO_{(g)} + Br_{2\ (g)} \rightarrow 2\ NOBr_{(g)}$$

119. The atmospheric decomposition of ozone is a slow, two-step reaction with the overall equation: $2\ O_3 \rightarrow 3\ O_2$

The first step in this decomposition is

$$O_3 \rightarrow O_2 + O \quad \text{(fast)}$$

a) Write the equation for the second step.
b) Which is the rate determining step?

120. A reaction has the following mechanism:

Step 1 : $HCOOH + H^+ \rightarrow HCOOH_2^+$ fast

Step 2 : $HCOOH_2^+ \rightarrow HCO^+ + H_2O$ slow

Step 3 : $HCO^+ \rightarrow H^+ + CO$ fast

a) Which is the rate determining step?
b) What is the NET equation for the overall reaction?

121. A mixture of natural gas and air in a reaction vessel does not react appreciably at room temperature. When a piece of platinum is inserted into the reaction vessel, the mixture explodes. Explain.

122. Explain how a catalyst increases the rate of a chemical reaction.

Answers:

94.	C	102.	B	110.	C
95.	C	103.	A	111.	D
96.	B	104.	C	112.	B
97.	B	105.	B	113.	C
98.	D	106.	D	114.	A
99.	A	107.	A	115.	D
100.	B	108.	D	116.	C
101.	B	109.	B		

117. An activated complex is a high-energy, unstable, short lived configuration of reactant atoms or molecules. **Or** A short-lived or unstable or high PE chemical species.

118. The possibility of 2 molecules of NO and 1 of Br_2 colliding at the same time with the proper energy and geometry (as the equation suggests) is infinitesimally small therefore it is more likely that the reaction mechanism is to be a two (or more) step process to allow the reactants to come together one step at a time.

119. a) $O_3 + O \rightarrow 2\ O_2$ b) The second step is the rate determining step.

120. a) Step 2 is the rate determining step. b) $HCOOH \rightarrow H_2O + CO$

121. The platinum is acting as a catalyst lowering the activation energy and making a large number of the collisions effective.

122. A catalyst provides an alternate lower energy pathway for the reaction to proceed by either combining with the reactant(s) to form an intermediate compound or by providing a site for the reaction to occur.