72. Consider the following experimental results:

	Experiment 1	Experiment 2
Reactants	$Fe^{2+}_{(aq)} + MnO_4{}^-{}_{(aq)}$	$MnO_4{}^-{}_{(aq)} + H_2C_2O_{4(aq)}$
Temperature	20°C	40°C
Concentration	0.5 M solutions	1.0 M solutions
Rates	Fast	Slow

Which factor would account for the faster reaction rate in Experiment 1?

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

73. Consider the reaction:

$$C_5H_{12(g)} + 8\,O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(g)}$$

Which of the following explains, in terms of collision theory, why this reaction occurs in more than one step?

A. a low $C_5H_{12(g)}$ concentration

B. low temperature of reactant mixture

C. low probability of a multi-particle collision

D. particles collide with insufficient kinetic energy

74. Which of the following factors only affects the rate of heterogeneous reactions?

A. nature of reactants
B. presence of a catalyst
C. temperature of reactants
D. surface area of reactants

75. Consider the following reactions in open systems:

I.	$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$
II.	$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
III.	$CaO_{(s)} + SiO_{2(s)} \rightarrow CaSiO_{3(s)}$
IV.	$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

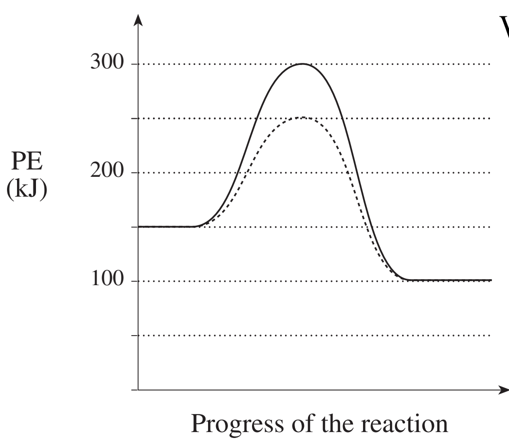
In which of the above could reaction rate be determined by $\frac{\Delta \text{ mass of system}}{\Delta \text{ time}}$?

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

76. Which of the following best describes *activation energy*?

A. PE of activated complex
B. (PE of products) – (PE of reactants)
C. (PE of reactants) – (PE of activated complex)
D. (PE of activated complex) – (PE of reactants)

77. Consider the following PE diagram:



Which of the following is true for the forward reaction?

	Reaction	PE of Activated Complex (kJ)	ΔH (kJ)
A.	catalyzed	100	–50
B.	uncatalyzed	300	–50
C.	catalyzed	250	+50
D.	uncatalyzed	150	–50

78. Consider the following reaction:

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

Why would this reaction probably involve more than one step?

A. There is insufficient activation energy.
B. This reaction has high activation energy.
C. Reactions between gases are typically slow.
D. A successful collision between more than two molecules is unlikely.

79. Consider the following reaction mechanism:

Step 1	$O_3 \rightarrow O_2 + O$
Step 2	$O_3 + O \rightarrow 2O_2$

Which of the following could represent the activated complex for Step 2?

A. O
B. O_2
C. O_3
D. O_4

Use the following information to answer questions 80 and 81:

When a candle $(C_{20}H_{42})$ burns, the following reaction occurs:

$$2C_{20}H_{42(s)} + 61O_{2(g)} \rightarrow 40CO_{2(g)} + 42H_2O_{(g)} + \text{heat}$$

80. If the rate of production of CO_2 is $0.98\,\text{g/min}$, what is the rate of oxygen consumption?

A. $0.47\,\text{g/min}$
B. $0.54\,\text{g/min}$
C. $0.71\,\text{g/min}$
D. $1.1\,\text{g/min}$

81. Which of the following properties could best be monitored in order to determine the reaction rate of the burning candle?

A. mass of $C_{20}H_{42(s)}$
B. pressure of $H_2O_{(g)}$
C. surface area of $C_{20}H_{42(s)}$
D. concentration of $C_{20}H_{42(s)}$

82. Which of the following is true of the kinetic and potential energies as reactant molecules approach each other to form an activated complex?

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

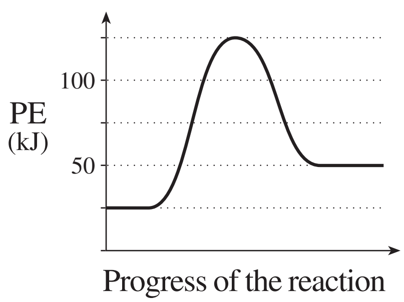
83. Which of the following are necessary for successful collisions between reactant molecules?

I.	high concentration
II.	sufficient energy
III.	correct geometry
IV.	presence of a catalyst

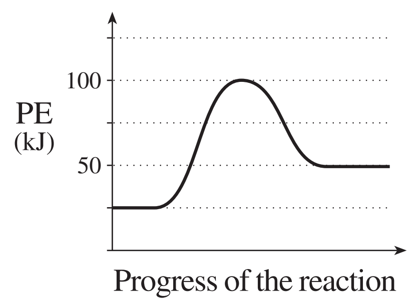
A. I and II only
B. II and III only
C. III and IV only
D. I, II and III only

84. Which of the following graphs most likely represents the slowest forward reaction?

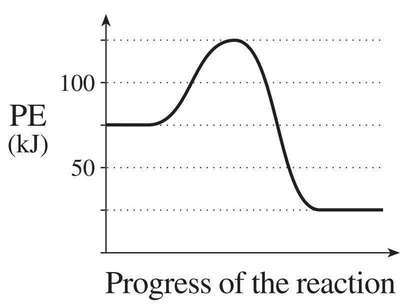
A.



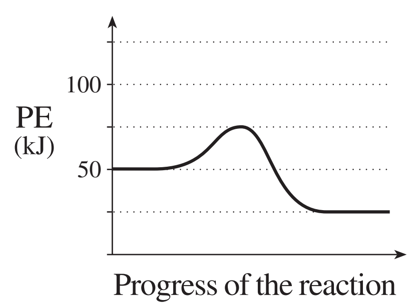
B.



C.



D.



85. For an exothermic reaction, which of the following is true?

A. $PE_{\textit{reactants}} > PE_{\textit{activated complex}} > PE_{\textit{products}}$

B. $PE_{\textit{products}} > PE_{\textit{activated complex}} > PE_{\textit{reactants}}$

C. $PE_{\textit{activated complex}} > PE_{\textit{reactants}} > PE_{\textit{products}}$

D. $PE_{\textit{activated complex}} > PE_{\textit{products}} > PE_{\textit{reactants}}$

86. Consider the following reaction:

$$O_{(g)} + O_{3(g)} \rightarrow 2O_{2(g)}$$

Which of the following describes how the reaction's catalyzed PE diagram compares to the reaction's uncatalyzed PE diagram?

	E_a	ΔH
A.	E_a (catalyzed) < E_a	unchanged
B.	E_a (catalyzed) > E_a	unchanged
C.	E_a (catalyzed) < E_a	ΔH (catalyzed) < ΔH
D.	unchanged	ΔH (catalyzed) < ΔH

87. Consider the following reaction mechanism:

Step 1.	$NO + O_3 \rightarrow NO_2 + O_2$
Step 2.	$O + NO_2 \rightarrow NO + O_2$

Which of the following substances is the catalyst?

A. O
B. O_2
C. NO
D. NO_2

88. Which of the following could represent the units for reaction rate?

A. g/mL
B. g/min
C. g/mol
D. mol/L

89. Consider the following reaction:

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

Which of the following would increase the reaction rate?

A. an increase in pressure
B. an increase in temperature
C. an increase in the concentration of H_2
D. an increase in the concentration of $ZnCl_2$

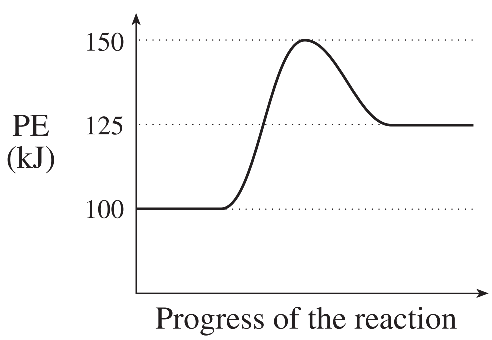
90. Consider the following reaction:

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

Which of the following is true of the activated complex relative to the reactants?

	KE	Stability
A.	high	stable
B.	low	stable
C.	high	unstable
D.	low	unstable

91. Consider the following PE diagram:



Which of the following is true for the forward reaction?

	ΔH (kJ)	PE of Activated Complex (kJ)
A.	–25	50
B.	–25	150
C.	+25	50
D.	+25	150

92. Which of the following could describe a catalyst?

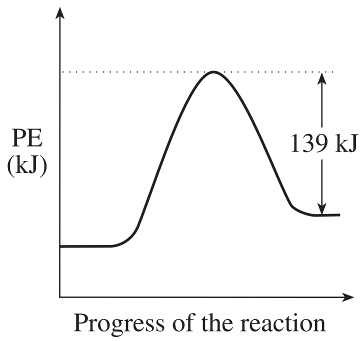
A. A substance that increases the reaction time.
B. A substance that provides an alternate mechanism with a higher activation energy.
C. A substance that is formed in one step and used up in a subsequent step in a reaction mechanism.
D. A substance that is used up in one step and reformed in a subsequent step in a reaction mechanism.

93. The following forward reaction has an $E_a = 167\,\text{kJ}$:

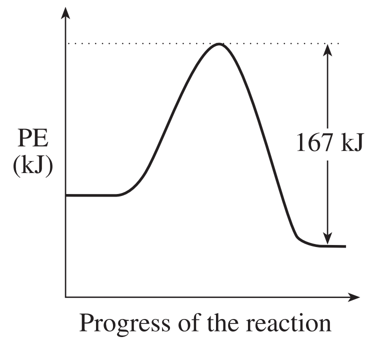
$$28\,\text{kJ} + H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

Which of the PE diagrams below represents this reaction?

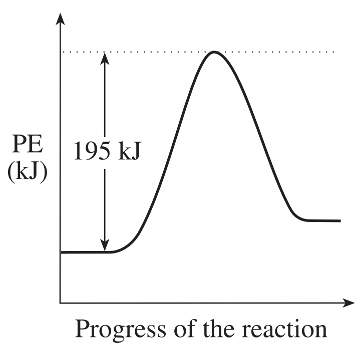
A.



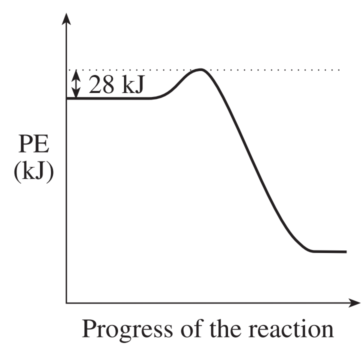
B.



C.



D.



94. Which of the following reactions is most likely to proceed at the greatest rate under standard conditions?

A. $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$
B. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$
C. $Cu_{(s)} + Cl_{2(g)} \rightarrow CuCl_{2(s)}$
D. $2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(\ell)} + K_2SO_{4(aq)}$

95. Nitrogen monoxide and hydrogen react according to the following equation:

$$2NO_{(g)} + 2H_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$$

If the rate of hydrogen consumption is $0.087\,\text{g/min}$, what is the rate of nitrogen production?

A. $0.044\,\text{g/min}$
B. $0.61\,\text{g/min}$
C. $1.2\,\text{g/min}$
D. $2.4\,\text{g/min}$

96. A student placed 3.0 g of Mg into some HCl in two different experiments. In each case, it reacted according the following equation:

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

In the first experiment, it took 3.2 minutes for all of the Mg to react. In the second experiment, it took 5.4 minutes for all of the Mg to react. Which of the following could account for the change in rate of the second experiment?

A. A catalyst was added.
B. The Mg was powdered.
C. The $[H_2]$ was decreased.
D. The temperature was decreased.

97. 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 temperature
D. changing the average kinetic energy

98. Consider the following reaction:

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

As a molecule of H_2 approaches a molecule of I_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

99. Which of the following reactions is endothermic?

A. $H_{2(g)} + S_{(s)} \rightarrow H_2S_{(g)} + 20\,kJ$
B. $4Fe_{(s)} + 3O_{2(g)} - 821\,kJ \rightarrow 2Fe_2O_{3(s)}$
C. $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)}$ $\quad \Delta H = +393\,kJ$
D. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$ $\quad \Delta H = -92\,kJ$

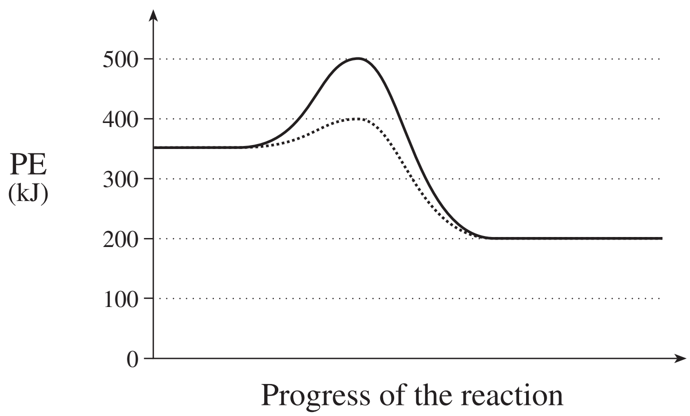
100. A reaction has the following mechanism:

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	$N_2O + H_2 \rightarrow N_2 + H_2O$

Which of the following substances is a reaction intermediate?

A. H_2
B. NO
C. H_2O
D. N_2O

101. Consider the following PE diagram:



Which of the following is true of the **reverse** reaction?

		E_a(kJ)	ΔH(kJ)
A.	catalyzed	200	−150
B.	catalyzed	200	+150
C.	uncatalyzed	300	−150
D.	uncatalyzed	500	+150

102. Consider the following reaction mechanism for the formation of NO_2.

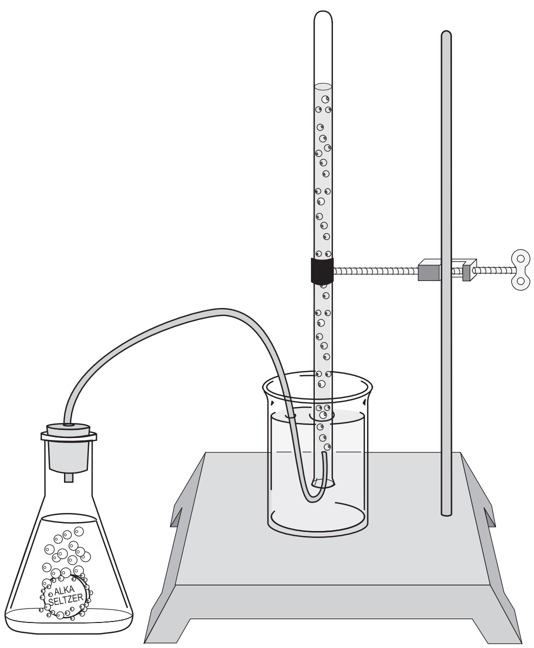
Step 1	$2NO \rightarrow N_2O_2$
Step 2	____________ $\rightarrow$ ____________
Overall	$2NO + O_2 \rightarrow 2NO_2$

a) Complete Step 2. **(2 marks)**

b) Define the term *reaction intermediate*. **(2 marks)**

c) Identify a reaction intermediate in the above mechanism. **(1 mark)**

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



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

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

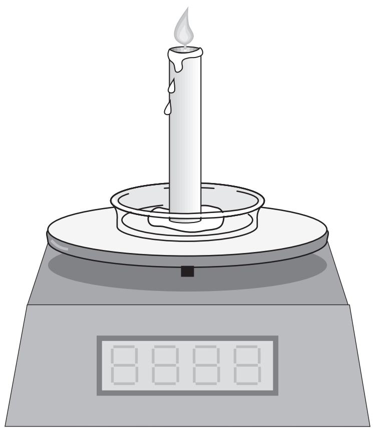
i) 0 – 10 s ii) 10 – 20 s

b) Suggest a reason why the rate of reaction from 0 to 10.0 s is slower than the rate from 10.0 to 20.0 s ?

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

104. 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:

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



The following data is observed:

Time (min)	Mass of Candle (g)
0.0	25.6
6.0	25.1
12.0	24.5
18.0	23.9
24.0	23.4
30.0	22.8

a) Calculate the average rate of consumption of paraffin in g/min for the time interval 12.0 to 24.0 minutes.

b) Calculate the rate of CO_2 production in mol/min for the time interval 12.0 to 24.0 minutes.

105. Consider the following proposed reaction mechanism:

Step 1	$Fe^{3+} + H_2O_2 \rightarrow FeH_2O_2^{3+}$
Step 2	$FeH_2O_2^{3+} \rightarrow FeOH^{3+} + HO$
Step 3	$HO + H_2O_2 \rightarrow H_2O + HO_2$
Step 4	$FeOH^{3+} + HO_2 \rightarrow Fe^{3+} + H_2O + O_2$

a) Write the overall reaction.

b) Define the term *catalyst* and identify a catalyst in the above mechanism.

106. Consider the following reaction:

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

The rate of decomposition of $C_{12}H_{22}O_{11}$ is 0.75 mol/min .
What mass of C is produced in 10.0 seconds?

107. Define the term *activation energy*.

108. Consider the reaction:

$$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(g)}$$

At certain conditions, 0.15 mol CO_2 is produced in 2.0 minutes.
What is the rate of consumption of C_2H_4 in g/s ?

109. Define the term *reaction mechanism.*

110. Consider the reaction:

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

A 10.0 g sample of Al reacts completely in excess HCl in 300.0 s.
What is the rate of production of H_2 in mol/s ?

111. Using collision theory, give **two** reasons why reactions occur more rapidly at a higher temperature.

112. Consider the reaction:

$$2H_2O_{(\ell)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

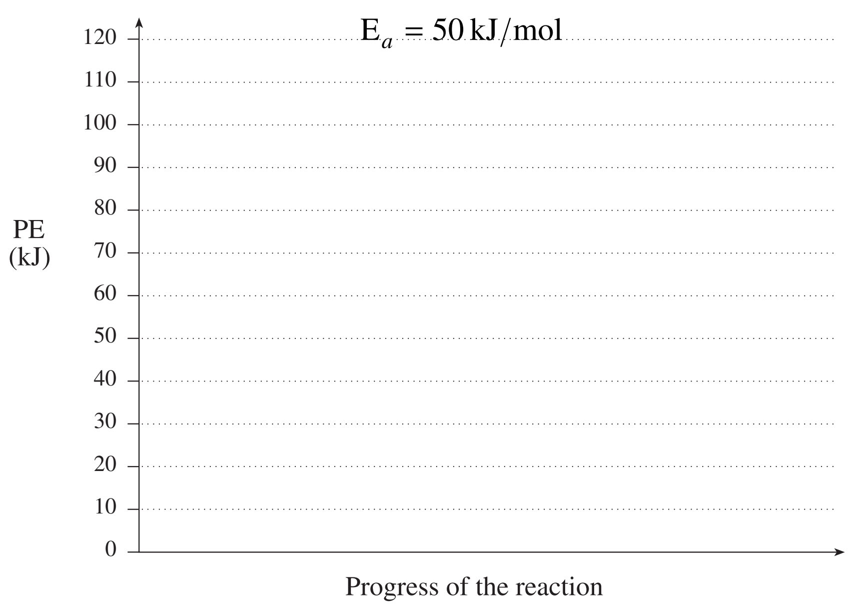
The rate of production of O_2 is 1.2×10^{-2} mol/s . How many seconds will it take to decompose 100.0 g H_2O ?

113. Define the term *catalyst*.

114. Using the axes below, sketch a PE diagram for the reacting system where:

$$\Delta H = -30 \text{ kJ/mol}$$

$$E_a = 50 \text{ kJ/mol}$$



115. Consider the following reaction mechanism:

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	$N_2O + H_2 \rightarrow N_2 + H_2O$

a) Determine the overall reaction.

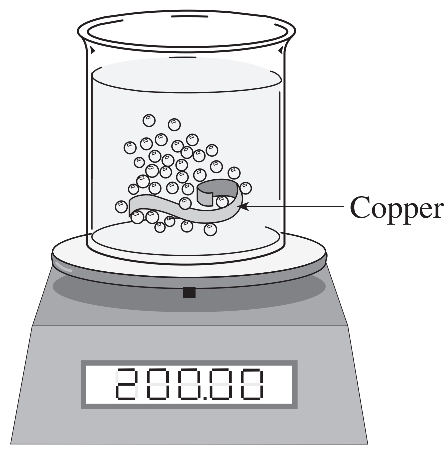
b) Identify a reaction intermediate.

116. Consider the following reaction:

$$3Cu_{(s)} + 8HNO_{3(aq)} \rightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(\ell)}$$

A piece of copper is added to a nitric acid solution in an open beaker, allowing the $NO_{(g)}$ to escape. The following data was obtained:

TIME (min)	MASS OF BEAKER AND CONTENTS (g)
0.0	200.00
1.0	197.50
2.0	195.45
3.0	193.55
4.0	191.70
5.0	189.90
6.0	188.15
7.0	186.45
8.0	184.80



a) Calculate the reaction rate for the time period 2.0 to 6.0 min.

b) Calculate the mass of copper consumed in the first 5 minutes.

117. Using collision theory, explain why reactions between two solutions occur more rapidly than reactions between two solids.

118. Consider the following reaction in an open flask:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

A 155.0 g sample of $CaCO_{3(s)}$ is placed in the flask and $HCl_{(aq)}$ is added. The reaction consumes $HCl_{(aq)}$ at an average rate of 0.200 mol/min for 10.0 min. What mass of $CaCO_{3(s)}$ remains?

119. a) Write the equation for Step 3 in the following reaction mechanism.

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	**?**
Overall Reaction	$2NO + 2H_2 \rightarrow N_2 + 2H_2O$

b) Identify a reaction intermediate in the above mechanism.

120. Consider the following reaction:

$$Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgBr_{2(aq)} + H_{2(g)} + \text{energy}$$

In terms of collision theory, describe how each of the factors below would influence the reaction rate.

a) Increasing the concentration of HBr:

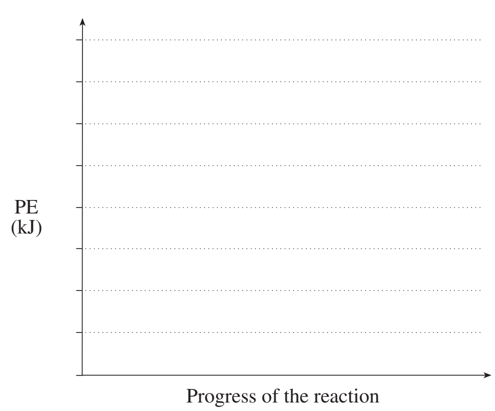
b) Decreasing the temperature:

c) Increasing the surface area of Mg:

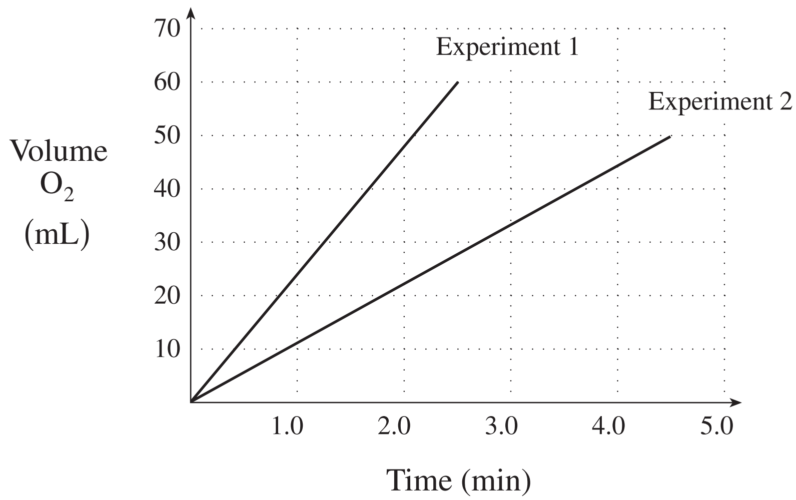
121. Consider the following reaction mechanism:

Step 1	$NO_{(g)} + O_{2(g)} \rightarrow NO_{3(g)}$ slow
Step 2	$NO_{3(g)} + NO_{(g)} \rightarrow 2NO_{2(g)}$

The overall reaction is exothermic. Sketch a PE diagram on the axes below to describe the energy changes that occur as the reaction takes place.



122. The release of $O_{2(g)}$ resulting from the decomposition of bleach was measured in two different experiments. Data was collected and the following graph was drawn:



a) Calculate the average rate of reaction for each experiment.

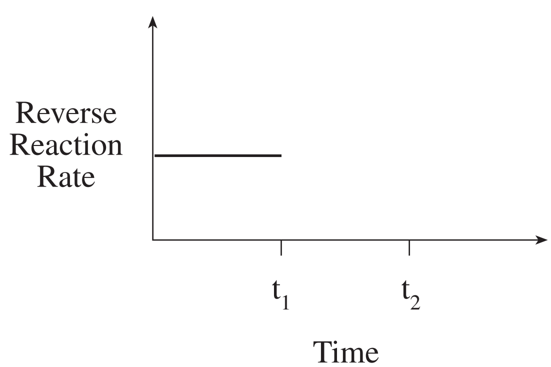
b) Identify a variable from Experiment 1 and how it was changed to produce the different reaction rate for Experiment 2. Explain using collision theory.

123. Consider the following equilibrium:

$$Al(H_2O)_4(OH)_2{}^{+}{}_{(aq)} \rightleftarrows Al(H_2O)_3(OH)_{3(s)} + H^{+}{}_{(aq)}$$

a) Some $HCl_{(aq)}$ is added to the equilibrium. What happens to the amount of solid $Al(H_2O)_3(OH)_3$? Explain.

b) The HCl is added at time t_1 and equilibrium is re-established at time t_2. On the axis below, sketch what happens to the reverse reaction rate.



124. When solid sodium is placed in water at room temperature, an immediate, violent reaction occurs:

$$2Na_{(s)} + 2H_2O_{(\ell)} \rightarrow 2NaOH_{(aq)} + H_{2(g)} + \text{energy}$$

a) Describe two methods that could be used to experimentally determine the rate of reaction.

b) Would you expect the activation energy of this reaction to be high or low? Explain, using collision theory.

125. Consider the following overall reaction which is exothermic:

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

a) Complete the proposed two-step reaction mechanism.

Step 1	$NO + NO \rightarrow N_2O_2$
Step 2	______________________

b) Describe how adding a catalyst would affect the activation energy and ΔH for the overall reaction?

Multiple Choice Answers:

1	A	6	B	11	C	16	D	21	D	26	D	31	C	36	D	41	B	46	D
2	B	7	D	12	D	17	B	22	C	27	A	32	D	37	A	42	C	47	D
3	B	8	D	13	B	18	C	23	B	28	A	33	D	38	C	43	C	48	A
4	A	9	C	14	B	19	A	24	D	29	D	34	B	39	C	44	B	49	C
5	A	10	B	15	D	20	C	25	D	30	A	35	A	40	B	45	D	50	B

51	D	56	C	61	C	66	B	71	A	76	D	81	A	86	A	91	D	96	D
52	A	57	C	62	D	67	B	72	C	77	B	82	B	87	C	92	D	97	A
53	C	58	A	63	C	68	A	73	C	78	D	83	B	88	B	93	A	98	B
54	D	59	A	64	C	69	D	74	D	79	D	84	A	89	B	94	D	99	C
55	D	60	C	65	B	70	C	75	B	80	D	85	C	90	D	95	B	100	D

101 B

Written solutions:

102. a) $N_2O_2 + O_2 \rightarrow 2NO_2$

b) A species that is produced and then used up in a later step.

c) N_2O_2

103. a) i)

$$\text{rate} = \frac{\Delta \text{vol}}{\Delta t} = \frac{3.0\text{ mL} - 0.0\text{ mL}}{10.0\text{ s}} = \frac{3.0\text{ mL}}{10.0\text{ s}} = 0.30\text{ mL/s}$$

ii)

$$\text{rate} = \frac{\Delta \text{vol}}{\Delta t} = \frac{20.0\text{ mL} - 3.0\text{ mL}}{20.0\text{ s} - 10.0\text{ s}} = \frac{17.0\text{ mL}}{10.0\text{ s}} = 1.70\text{ mL/s}$$

b) The surface area of the tablet increases as the tablet crumbles.

c) The rate decreases during the interval because the surface area decreases.

104. a)

$$r = \frac{\Delta \text{mass}}{\Delta t} = \frac{1.1\text{ g}}{12.0\text{ min}} = 0.092\text{ g/min}$$

b)

$$\text{rate} = 0.092\text{ g/min} \times \frac{1\text{ mol } C_{28}H_{58}}{394.0\text{ g}} \times \frac{56\text{ mol } CO_2}{2\text{ mol } C_{28}H_{58}} = 6.5 \times 10^{-3}\text{ mol/min}$$

105. a) $2H_2O_2 \rightarrow 2H_2O + O_2$ b) Definition: A species which speeds up a reaction by providing a lower energy pathway.

Catalyst: Fe^{3+}

106.

$$\text{Rate of C production} = \frac{0.75\,\text{mol}\,C_{12}H_{22}O_{11}}{\text{min}} \times \frac{12\text{ mol C}}{1\text{ mol }C_{12}H_2O_{11}}$$

$$= \frac{9.0\,\text{mol}}{\text{min}}$$

$$\text{Mass of C in } 10\,\text{s} = \left(\frac{9.0\,\text{mol}}{\text{min}}\right) \times \left(\frac{12.0\,\text{g}}{\text{mol}}\right) \times (10.0\,\text{s}) \times \left(\frac{1\,\text{min}}{60\,\text{s}}\right)$$

$$= 18\,\text{g}$$

107. Activation energy is the minimum amount of energy required to form the activated complex from the reactants.

108.

$$\text{rate of formation of } CO_2 = \frac{0.15\,\text{mol}}{2.0\,\text{min}}$$

$$= 0.075\,\text{mol/min}$$

$$\text{rate of consumption of } C_2H_4 = \frac{1}{2} \times \text{rate of formation of } CO_2$$

$$= 0.0375\,\text{mol/min}$$

$$= \frac{0.0375\,\text{mol } C_2H_4}{60\,\text{s}} \times \frac{28.0\text{g}}{\text{mol}}$$

$$= 1.8 \times 10^{-2}\ \text{g/s}$$

109. A reaction mechanism is a series of steps that result in the overall reaction.

110.

$$\text{mol Al} = 10.0\,\text{g} \times \frac{1\,\text{mol}}{27.0\text{g}} = 0.370\,\text{mol Al}$$

$$\text{mol } H_2 = 0.370\,\text{mol Al} \times \frac{3\,\text{mol } H_2}{2\,\text{mol Al}}$$

$$= 0.556\,\text{mol } H_2$$

$$\text{rate} = \frac{\text{change in moles}}{\text{time}}$$

$$= \frac{0.556\,\text{mol } H_2}{300.0\,\text{s}}$$

$$= 1.85 \times 10^{-3}\,\frac{\text{mol } H_2}{\text{s}}$$

111. There is a greater fraction of collisions with sufficient energy.

There are more frequent collisions.

112. $$\text{mol } H_2O = 100.0\text{ g } \frac{1\text{ mol}}{18.0\text{ g}} = 5.556\text{ mol}$$

$$\text{mol } O_2 = 5.556\text{ mol } H_2O \times \frac{1\text{ mol } O_2}{2\text{ mol } H_2O}$$

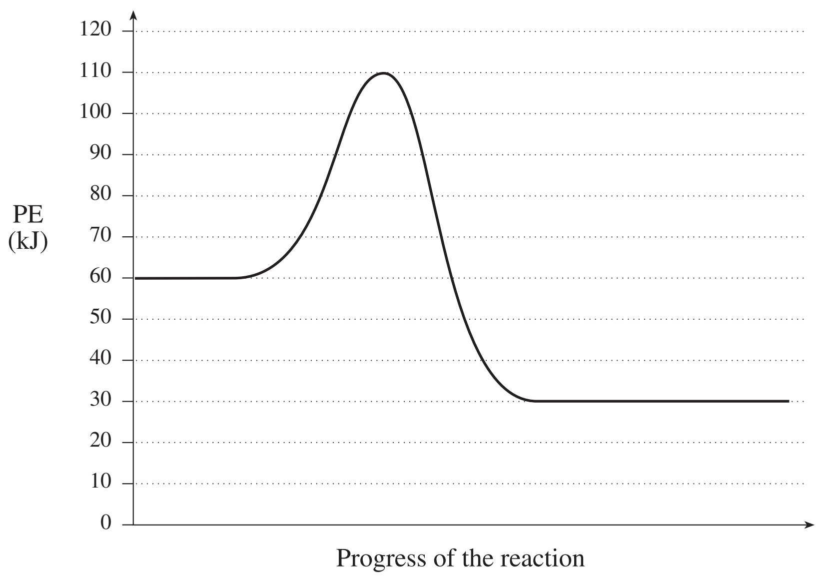
$$= 2.778\text{ mol}$$

$$\text{time} = \frac{\text{mol } O_2}{\text{rate}} = \frac{2.778\text{ mol}}{1.2 \times 10^{-2}\text{ mol/s}}$$

$$= 2.3 \times 10^2\text{ s}$$

113. A catalyst is a substance that increases the rate of a chemical reaction and may be recovered at the end of the reaction.

114.



1 mark for exothermic diagram

1 mark for $\Delta H = -30$kJ/mol

1 mark for $E_a = 50$kJ/mol

115. a) Overall Reaction: $2NO + 2H_2 \rightarrow N_2 + 2H_2O$ b) N_2O_2 **OR** N_2O

116. a) $$\text{rate} = \frac{\text{mass change}}{\text{time change}} = \frac{195.45\text{ g} - 188.15\text{ g}}{(6.0 - 2.0)\text{ min}}$$

$$= \frac{7.30\text{ g}}{4.0\text{ min}}$$

$$= 1.8\text{ g/min NO produced}$$

b) $$\text{moles NO produced} = \frac{200.00\text{ g} - 189.90\text{ g}}{30.0\text{ g/mol}} = 0.3367\text{ mol NO}$$

$$\text{moles Cu consumed} = 0.3367\text{ mol NO} \times \frac{3\text{ mol Cu}}{2\text{ mol NO}} = 0.5050\text{ mol Cu}$$

$$\text{mass Cu consumed} = 0.5050\text{ mol Cu} \times \frac{63.5\text{ g Cu}}{1\text{ mol Cu}} = 32.1\text{ g Cu}$$

117. • Particles must be able to collide to react.

• Only the particles on the surface of a solid are available for reaction. In a solution, all particles are available.

118. Amount of HCl reacting = 0.200 mol/min × 10.0 min = 2.00 mol

$$\text{Moles of } CaCO_3 \text{ reacting} = 2.00\,\text{mol HCl} \times \frac{1\,CaCO_3}{2\,HCl} = 1.00\,\text{mol } CaCO_3$$

$$\text{Mass of } CaCO_3 \text{ reacting} = 1.00\,\text{mol } CaCO_3 \times \frac{100.1\,\text{g}}{1\,\text{mol}} = 1.00 \times 10^2\,\text{g}$$

Mass remaining = 155.0 g − 100. g = 55 g

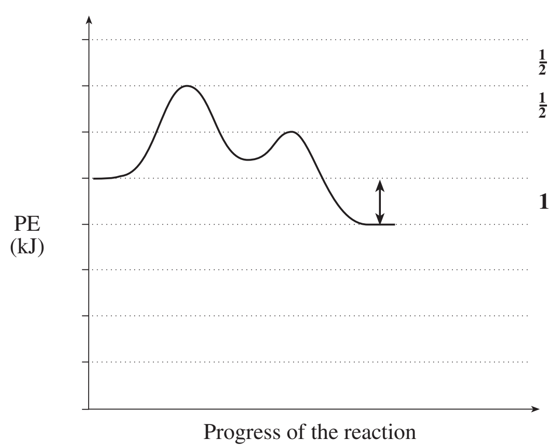
119. a) Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$ b) **Either** N_2O_2 **OR** N_2O

120. a) Greater concentration and more collisions. Therefore more successful collisions and a greater rate.

b) Fewer collisions with sufficient energy to overcome PE barrier. Therefore, a lower rate.

c) Increased surface area leads to more collisions and more successful collisions. Therefore, a higher rate.

121.



½ mark for 2 humps

½ mark for first hump higher than second

1 mark for exothermic reaction

122. a)

$$\text{Experiment 1: } \frac{60\,\text{mL}}{2.5\,\text{min}} = 24\,\text{mL/min}$$

$$\text{Experiment 2: } \frac{50\,\text{mL}}{4.5\,\text{min}} = 11\,\text{mL/min}$$

b)

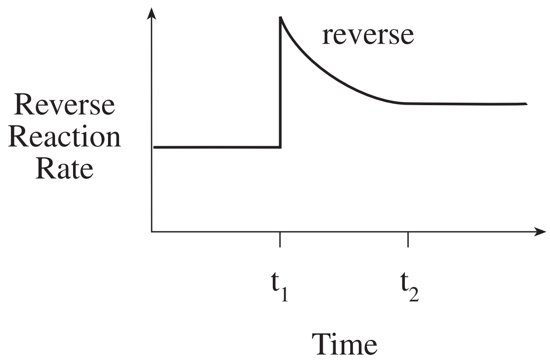
Variable/Change	Explanation
Temperature is decreased.	Lower fraction of effective collisions.

OR

Concentration of reactants was decreased.	Fewer collisions.

123. a) The amount of solid decreases because the equilibrium shifts left.

b)



124. a) **Any two of the following per unit time:**

- Δ mass Na
- Δ volume H_2
- Δ temperature
- Δ pH
- Δ pressure

b) The reaction is very fast so many collisions at room temperature would have the needed energy to be successful. The activation energy of this reaction would be low.

125. a)

Step 1	$NO + NO \rightarrow N_2O_2$
Step 2	$\mathbf{N_2O_2 + O_2 \rightarrow 2NO_2}$

b) A catalyst provides a different mechanism with a lower E_a .

Catalyst has no effect on ΔH.