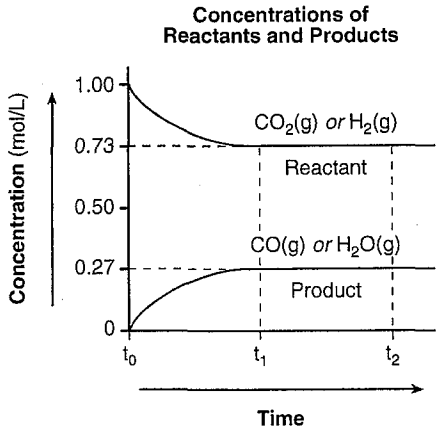
Name: Date:

Unit Review- Kinetics and Equilibrium

Base your answers to questions 1 and 2 on the information below.

At 550°C, 1.00 mole of $CO_2(g)$ and 1.00 mole of $H_2(g)$ are placed in a 1.00-liter reaction vessel. The substances react to form CO(g) and $H_2O(g)$. Changes in the concentrations of the reactants and the concentrations of the products are shown in the graph below.



1. What can be concluded from the graph about the concentrations of the reactants and the concentrations of the products between time t_1 and time t_2?

2. Determine the change in the concentration of $CO_2(g)$ between time t_0 and time t_1.

3. Base your answer to the following question on the information below.
The balanced equation below represents the decomposition of potassium chlorate.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

State why the entropy of the reactant is less than the entropy of the products.

4. Given the equation representing a reaction at equilibrium:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

Explain, in terms of collision theory, why the rate of the forward reaction *decreases* when the concentration of $N_2(g)$ is decreased.

5. State *two* methods to increase the rate of a chemical reaction and explain, in terms of particle behavior, how each method increases the reaction rate.

Base your answers to questions 6 and 7 on the information below.

A beaker contains 100.0 milliliters of a dilute aqueous solution of ethanoic acid at equilibrium. The equation below represents this system.

$$HC_2H_3O_2(aq) \leftrightarrow H^+(aq) + C_2H_3O_2^-(aq)$$

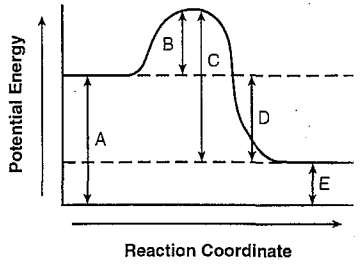
6. Describe what happens to the concentration of $H^+(aq)$ when 10 drops of concentrated $HC_2H_3O_2(aq)$ are added to this system.

7. Compare the rate of the forward reaction to the rate of the reverse reaction for this system.

8. Explain how a catalyst may increase the rate of a chemical reaction.

Base your answers to questions 9 and 10 on the information below.

The chemical reaction between methane and oxygen is represented by the potential energy diagram and balanced equation below.



$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4\ kJ$$

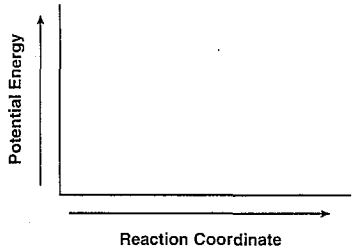
9. Explain, in terms of collision theory, why a lower concentration of oxygen gas *decreases* the rate of this reaction.

10. Which potential energy interval in the diagram represents the activation energy of the forward reaction?

11. Given the balanced equation representing a reaction:

$$N_2(g) + O_2(g) + 182.6\ kJ \rightarrow 2NO(g)$$

On the labeled axes below, draw a potential energy diagram for this reaction.

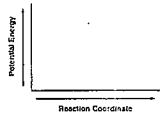


Base your answers to questions 12 through 14 on the equation below.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + 571.6\ kJ$$

12. Explain why the entropy of the system decreases as the reaction proceeds.

13. On the axes below, draw a potential energy diagram for the reaction represented by this equation.



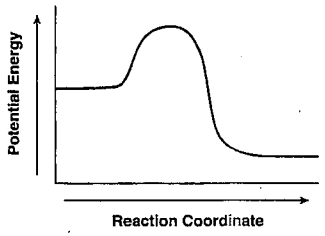
14. Identify the information in this equation that indicates the reaction is exothermic.

15. Base your answer to the following question on the information below.

The catalytic converter in an automobile changes harmful gases produced during fuel combustion to less harmful exhaust gases. In the catalytic converter, nitrogen dioxide reacts with carbon monoxide to produce nitrogen and carbon dioxide. In addition, some carbon monoxide reacts with oxygen, producing carbon dioxide in the converter. These reactions
are represented by the balanced equations below.

Reaction 1: $2NO_2(g) + 4CO(g) \rightarrow N_2(g) + 4CO_2(g) + 1198.4$ kJ
Reaction 2: $2CO(g) + O_2(g) \rightarrow 2CO_2(g) + 566.0$ kJ

The potential energy diagram below represents reaction 1 without a catalyst. On the same diagram, draw a dashed line to indicate how potential energy changes when the reaction is catalyzed in the converter.



Base your answers to questions 16 and 17 on the information and balanced equation below.

Given the equation for a reaction at equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + \text{energy}$$

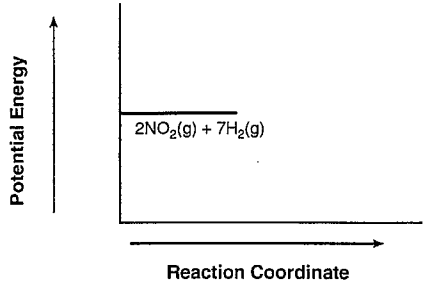
16. Explain, in terms of collisions between molecules, why increasing the concentration of $O_2(g)$ produces a *decrease* in the concentration of $SO_2(g)$.

17. Explain, in terms of LeChatelier's principle, why the concentration of $SO_2(g)$ increases when the temperature is increased.

Base your answers to questions 18 and 19 on the information below.

Given the reaction at equilibrium:

$$2NO_2(g) + 7H_2(g) \leftrightarrow 2NH_3(g) + 4H_2O(g) + 1127 \text{ kJ}$$



18. Explain, in terms of Le Chatelier's principle, why the concentration of $NH_3(g)$ *decreases* when the temperature of the equilibrium system increases.

19. Complete the potential energy diagram above for the forward reaction. Be sure your drawing shows the activation energy and the potential energy of the products.

Base your answers to questions 20 and 21 on the information below, which describes the smelting of iron ore, and on your knowledge of chemistry.

In the smelting of iron ore, Fe_2O_3 is reduced in a blast furnace at high temperature by a reaction with carbon monoxide. Crushed limestone, $CaCO_3$, is also added to the mixture to remove impurities in the ore. The carbon monoxide is formed by the oxidation of carbon(coke), as shown in the reaction below:

$$2\,C + O_2 \rightarrow 2\,CO + \text{energy}$$

Liquid iron flows from the bottom of the blast furnace and is processed into different alloys of iron.

20. Convert the melting point of iron metal to degrees Celsius.

21. Sketch a potential energy diagram for the reaction of carbon and oxygen that produces carbon monoxide.

Base your answers to questions 22 through 24 on the information below.

At room temperature, a reaction occurs when $KIO_3(aq)$ is mixed with $NaHSO_3(aq)$ that contains a small amount of starch. The colorless reaction mixture turns dark blue after a period of time that depends on the concentration of the reactants.

In a laboratory, 12 drops of a 0.02 M $NaHSO_3(aq)$ solution containing starch were placed in each of six test tubes. A different number of drops of 0.02 M $KIO_3(aq)$ and enough water to maintain a constant volume were added to each test tube and the time for the dark-blue color to appear was measured. The data were recorded in the table below.

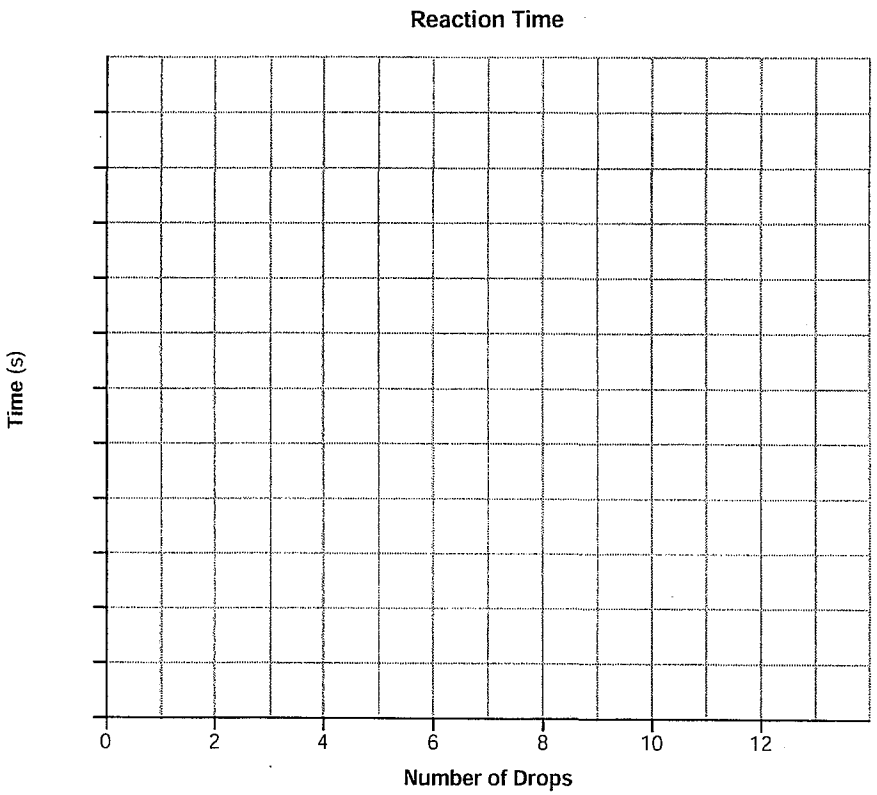
Data Table

Test Tube	A	B	C	D	E	F
Number of Drops of 0.02 M $KIO_3(aq)$	2	4	6	8	10	12
Time for Dark-Blue Color to Appear (s)	210.	88	49	39	33	27

22. Identify *one* factor, other than the concentration of the reactants, that would affect the rate of this reaction.

23. State how increasing the number of drops of 0.02 M $KIO_3(aq)$ used in the reaction affects the rate of reaction.

24. On the grid below:
- Mark an appropriate scale on the axis labeled "Time (s)."
- Plot the data from the data table. Circle and connect the points.



Base your answers to questions **25** through **27** on the information below.

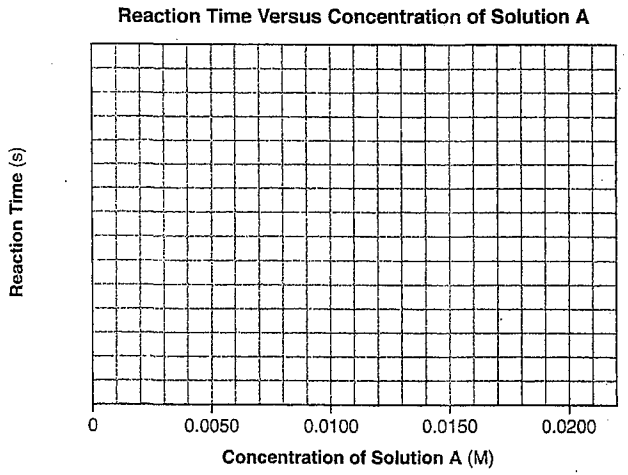
An experiment is performed to determine how concentration affects the rate of reaction. In each of four trials, equal volumes of solution *A* and solution *B* are mixed while temperature and pressure are held constant. The concentration of solution *B* is held constant, but the concentration of solution *A* is varied. The concentration of solution *A* and the time for the reaction to go to completion for each trial are recorded in the data table below.

Data Table

Trial	Concentration of Solution A (M)	Reaction Time (s)
1	0.0200	4.5
2	0.0150	7.0
3	0.0100	12.0
4	0.0050	20.0

25. Identify *one* factor, other than the concentration of the solutions, that can affect the rate of this reaction.

26. On the grid below, mark an appropriate scale on the axis labeled "Reaction Time (s)."



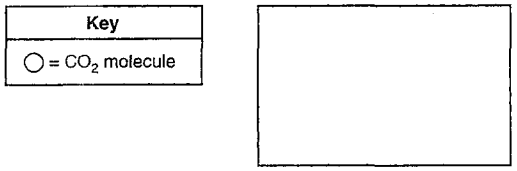
27. Describe the relationship between the concentration of solution *A* and the time for the reaction to go to completion.

Base your answers to questions 28 and 29 on the information below.

A phase change for carbon dioxide that occurs spontaneously at 20.°C and 1.0 atmosphere is represented by the balanced equation below.

$$CO_2(s) + \text{energy} \rightarrow CO_2(g)$$

28. Below, use the key to draw *at least five* molecules in the box to represent CO_2 after this phase change is completed.



29. Describe what happens to the potential energy of the CO_2 molecules as this phase change occurs.

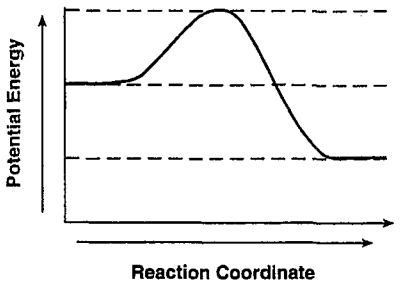
30. Base your answer to the following question on the information below.

A 1.0-gram strip of zinc is reacted with hydrochloric acid in a test tube. The unbalanced equation below represents the reaction.

$$\_\_\_ Zn(s) + \_\_\_ HCl(aq) \rightarrow \_\_\_ H_2(g) + \_\_\_ ZnCl_2(aq)$$

Explain, in terms of collision theory, why using 1.0 grams of powdered zinc, instead of the 1.0-gram strip of zinc, would have increased the rate of the reaction.

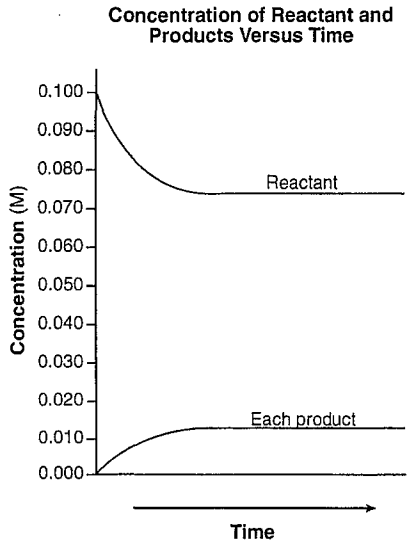
31. On the potential energy diagram, draw an arrow to represent the activation energy of the forward reaction.



Base your answers to questions 32 and 33 on the information below.

In a laboratory, 0.100 mole of colorless hydrogen iodide gas at room temperature is placed in a 1.00-liter flask. The flask is sealed and warmed, causing the HI(g) to start decomposing to $H_2(g)$ and $I_2(g)$. Then the temperature of the contents of the flask is kept constant.

During this reaction, the contents of the flask change to a pale purple-colored mixture of HI(g), $H_2(g)$, and $I_2(g)$. When the color of the mixture in the flask stops changing, the concentration of $I_2(g)$ is determined to be 0.013 mole per liter. The relationship between concentration and time for the reactant and products is shown in the graph below.



32. Calculate the mass of $I_2(g)$ in the flask at equilibrium. Your response must include *both* a correct numerical setup and the calculated result.

33. State, in terms of concentration, evidence that indicates the system in the flask has reached equilibrium.

Base your answers to questions 34 and 35 on the information below.

Given the equilibrium equation at 298 K:

$$KNO_3(s) + 34.89 \text{ kJ} \leftrightarrow K^+(aq) + NO_3^-(aq)$$

34. The equation indicates that KNO_3 has formed a saturated solution. Explain, in terms of equilibrium, why the solution is saturated.

35. Describe, in terms of *LeChatelier's principle*, why an increase in temperature increases the solubility of KNO_3.

Base your answers to questions 36 and 37 on the information below.

A student wishes to investigate how the reaction rate changes with a change in concentration of HCl(aq).

Given the reaction:

$$Zn(s) + HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$$

36. Describe the effect of increasing the concentration of HCl(aq) on the reaction rate and justify your response in terms of *collision theory*.

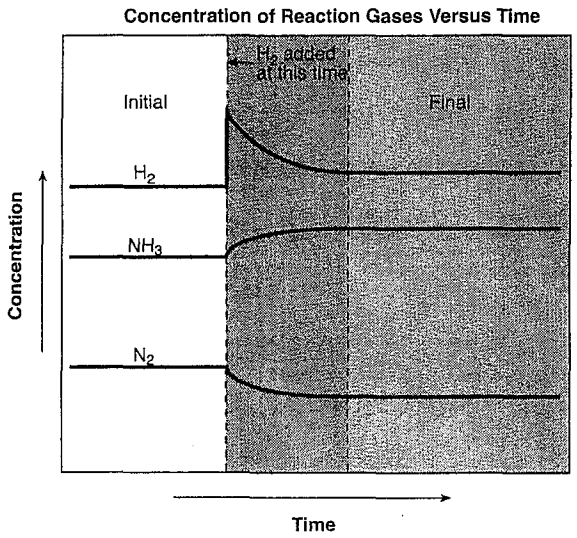
37. Identify one other variable that might affect the rate and should be held constant during this investigation.

Base your answers to questions **38** through **40** on the information below

Nitrogen gas, hydrogen gas, and ammonia gas are in equilibrium in a closed container at constant temperature and pressure. The equation below represents this equilibrium.

$$N_2(g) + 3H_2 \leftrightarrow 2NH_3(g)$$

The graph below shows the initial concentration of each gas, the changes that occur as a result of adding $H_2(g)$ to the system, and the final concentrations when equilibrium is reestablished.



38. Explain, in terms of collision theory, why the concentration of $H_2(g)$ begins to decrease immediately after more $H_2(g)$ is added to the system.

39. What information on the graph indicates that the system was initially at equilibrium?

40. Explain, in terms of LeChatelier's principle, why the final concentration of $NH_3(g)$ is greater than the initial concentration of $NH_3(g)$.

41. Explain, in terms of collision theory, why an increase in temperature increases the rate of a chemical reaction.

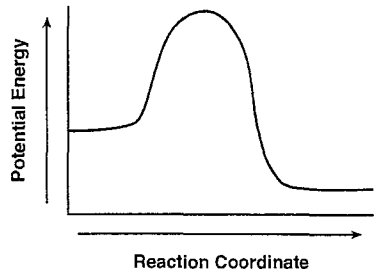
42. Base your answer to the following question on the information below.

The equilibrium equation below is related to the manufacture of a bleaching solution. In this equation, Cl(aq) means that chloride ions are surrounded by water molecules.

$$Cl_2(g) + 2OH^-(aq) \rightleftharpoons OCl^-(aq) + Cl^-(aq) + H_2O(\ell)$$

Explain, in terms of collision theory, why increasing the concentration of $Cl_2(g)$ increases the concentration of $OCl^-(aq)$ in this equilibrium system.

43. A potential energy diagram for a chemical reaction is shown below. On this diagram, draw a curve to show how the potential energy diagram will change when a catalyst is added to the reaction.



Base your answers to questions **44** and **45** on the information below.

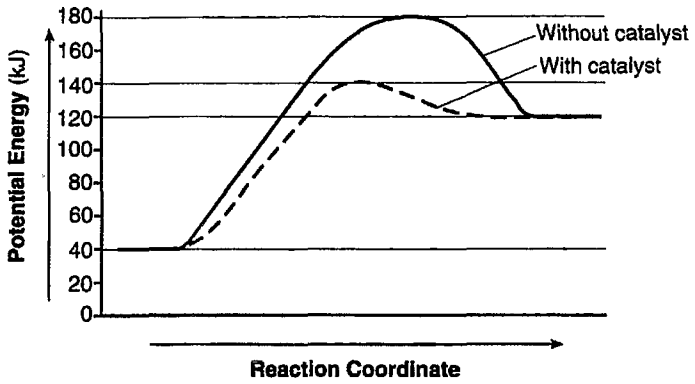
Given the reaction at equilibrium:

$$2NO_2(g) \leftrightarrow N_2O_4(g) + 55.3\ kJ$$

44. Explain, in terms of Le Chatelier's principle, why the equilibrium shifts to the right to relieve the stress when the pressure on the system is increased at constant temperature.

45. Explain, in terms of energy, why the forward reaction is exothermic.

Base your answers to questions 46 through 48 on the potential energy diagram below.

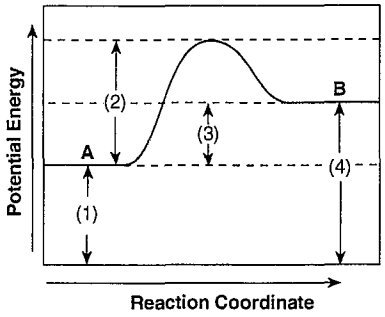


46. Explain, in terms of the function of a catalyst, why the curves on the potential energy diagram for the catalyzed and uncatalyzed reactions are different.

47. What is the activation energy for the forward reaction with the catalyst?

48. What is the heat of reaction for the forward reaction?

Base your answers to questions 49 through 51 on the potential energy diagram and the equation below.



$$2\ C(s) + H_2(g) + 227.4\ kJ \rightarrow C_2H_2(g)$$

49. Describe how the potential energy diagram will change if a catalyst is added.

50. If 682.2 kilojoules are absorbed, how many moles of C $_2H_2(g)$ are produced?

51. The letter B represents which chemical formula or formulas in the equation?

52. Base your answer to the following question on the information and equation below.

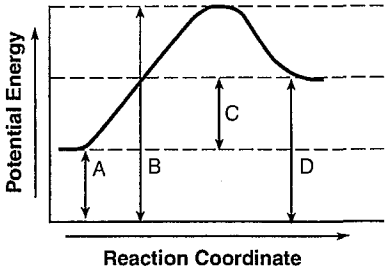
Human blood contains dissolved carbonic acid, H_2CO_3, in equilibrium with carbon dioxide and water. The equilibrium system is shown below.

$$H_2CO_3(aq) \leftrightarrow CO_2(aq) + H_2O(\ell)$$

Explain, using LeChatelier's principle, why decreasing the concentration of CO_2 decreases the concentration of H_2CO_3.

Base your answers to questions *53* through *55* on the information and potential energy diagram below.

Chemical cold packs are often used to reduce swelling after an athletic injury. The diagram represents the potential energy changes when a cold pack is activated.



53. Identify a reactant listed in Reference Table *I* that could be mixed with water for use in a chemical cold pack.

54. Which lettered interval on the diagram represents the heat of reaction?

55. Which lettered interval on the diagram represents the potential energy of the products?

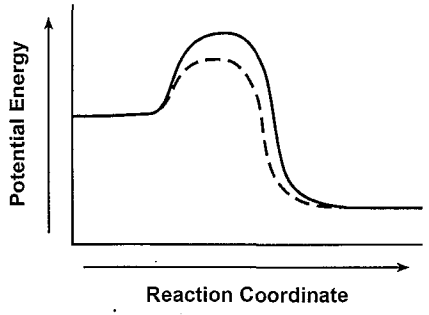
1. – Between time t_1 and time t_2, the concentrations of the reactants and the concentrations of the products are no longer changing. – The concentrations of the reactants and – The concentration of each reacta concentration of each product is 0.

2. – -0.27 mol/L – 0.27 mol/L

3. – The gaseous product is more disord The solid reactant is more ordered

4. *Examples:* – The rate of the forward r are fewer N_2 molecules to collide v slows down because collisions are l collisions

5. *Examples:* – Increasing the temperatu reacting particles to move faster an Increasing the concentration increa collisions.– Increasing the surface area (solid reactant) allows a greater number of particles to collide.– Adding a catalyst provides an alternate way for the particles to react.



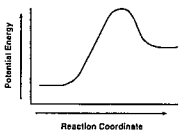
6. *Examples:* The H^+(aq) concentration increases – PH_3 – increases

7. The rate of the forward reaction equals the rate of the reverse reaction.

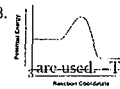
8. Examples: –lowers activation energy –provides an alternate reaction pathway –brings particles together –forms a different activated complex at lower activation energy

9. Acceptable responses include, but are not limited to: • A lower concentration of oxygen gas decreases the number of effective collisions between O_2 molecules and CH_4 molecules.

10. *B*

11. 

12. *Examples:* – A liquid is formed from gases. – A compound is formed from its elements. – The number of gas particles in the system decreases.

13.  are used. – The reaction occurs faster.

14. *Examples:* – Heat term is on the right side of the equation. – The 571.6kJ is a product.

15. An appropriate line is drawn.

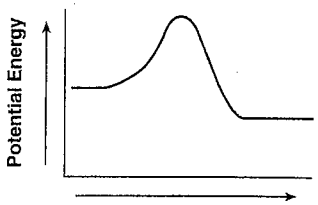
16. Examples: – A higher concentration of O_2(g) causes more collisions and reactions with SO_2(g) molecules, decreasing SO $_2$(g) concentration. – More collisions between reactant shift the reaction to the right.

17. Examples: – An increase in temperature favors the endothermic reaction, which produces more SO_2(g). – The reaction shifts to the left, increasing the concentration of SO_2(g).

18. An increase in temperature favors the endothermic (reverse) reaction.

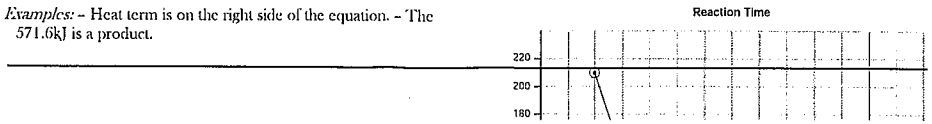
19. Essay

20. 1.535

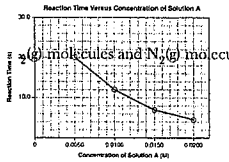
21. 

22. the temperature of the reactants or a catalyst

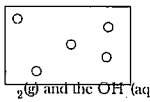
23. -Increasing the number of drops of KIO_3(aq) increases the rate of reaction. -The reaction takes less time if more drops of KIO

24. 

25. • temperature • addition of a catalyst

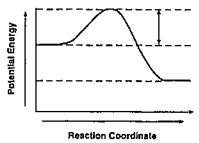
26. 

27. • As the concentration of solution *A* was decreased, the time for the reaction to go to completion increased. • As the concentration of *A* is decreased, the rate of reaction decreases.

28. 

29. • The potential energy of the CO_2 molecules increases. • The CO_2(g) molecules have more potential energy than the CO_2(s) molecules.

30. Example: The greater surface area in powdered zinc would have resulted in more frequent collisions between the zinc atoms and the hydrogen ions in the HCl(aq).

31. 

32. 126.905 × 2 = 253.810 g/mol; (0.013 M)(1.00 L)(253.810 g/mol) mass = 0.013 × 254; 3.3 g

33. *Examples:* – The concentration of each product and the concentration of the reactant remain the same. – The concentrations have reached constant levels. – The horizontal lines on the graph show that the concentrations are constant.

34. The rate of dissolving KNO_3 is equal to the rate of recrystallizing KNO_3 *or* The KNO_3 is going into the solution at the same rate it precipitates out of the solution

35. Increasing the temperature favors the forward, endothermic reaction *or* Adding heat shifts the reaction to the right

36. Examples: – rate ↑, more collisions; – The rate will increase because the higher concentration of HCl will lead to a greater number of collisions.

37. Examples: – temperature; – surface area of Zn; – amount of Zn; – Zn; – concentration of Zn; – [Zn]

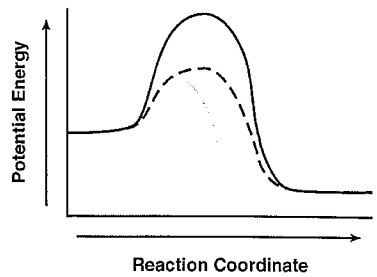
38. *Examples:* – Adding H_2(g) causes more collisions between H $_2$(g) molecules and N_2(g) molecules. Therefore, more H_2(g) reacts, reducing the H_2(g) concentration. – More collisions between H_2 and N_2 produce NH_3, so more H_2 is used up.

39. *Examples:* – The initial concentration of each gas is constant. – Concentrations stay the same.

40. *Examples:* – The stress of adding H2(g) shifts the reaction to the right, producing NH3(g). – The reaction shifts to the right to relieve the stress.

41. --As molecules acquire more kinetic energy, the number of effective collisions increases. higher temperature, greater frequency of collisions

42. *Examples:* – The concentration of OCl^-(aq) increases because there will be a greater number of effecti collisions between the Cl $_2$(g) and the OH^-(aq) – more collisions between Cl_2(g) and OH^-(aq)

43. 

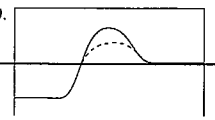
44. *Examples:* – Equilibrium shifts towards the fewer number of moles of gas – The reaction shifts to the side that would result in a reduction of pressure – fewer moles of gas, less pressure

45. *Examples:* – Potential energy of the product is less than potential energy of the reactant – More energy is released than absorbed – Energy appears on the right

46. Acceptable responses include, but are not limited to:
A catalyst provides an alternate reaction pathway that has a lower activation energy than an uncatalyzed reaction.
A catalyst speeds up the reaction, lower activation energy

47. +100 kj or 100 kj.

48. +80 kj or 80 kj.

49. 

Responses include, but are not limited to: Arrow 2 gets shorter • The activation energy would be lower • The peak of the curve is lower

50. three

51. $C_2H_2(g)$

52. Acceptable responses: Removing CO_2 disrupts equilibrium and thus the system must shift to create more CO_2 from the H_2CO_3 in order to restore equilibrium; Equilibrium shifts to the right; H_2CO_3 decreases to remove the stress of changing the CO_2.

53. Allow credit for KNO_3 or NaCl or NH_4Cl or NH_4NO_3, or potassium nitrate or sodium chloride or ammonium chloride or ammonium nitrate.

54. Allow credit for C.

55. Allow credit for D.