(Key)

RC- Kinetics and Equilibrium Test Review Stations

Station 1- Collision Theory and Factors Affecting Reaction Rate

1. Explain the collision theory of reactions.

For a rxn to occur, reactant particles must collide w/ sufficient kinetic energy & proper orientation

2. Fill out the following table to review the factors affecting reaction rates:

Factor	Effect on Reaction Rate	Explanation
Temperature	↑ temp, ↑ rate	@ higher temps, particles collide more frequently & w/ more kinetic energy
Concentration	↑ concentration, ↑ rate	@ higher concentrations, more reactant particles are available, so more collisions
Surface Area	↑ surface area, ↑ rate	w/ greater surface area, more reactant particles are exposed, so more collisions
Pressure (for gases)	↑ pressure, ↑ rate	as pressure ↑, gas particles are confined to a smaller volume, so collisions are more frequent
Nature of Reactants	Dissolved (aq) ionic substances react fastest	when dissolved (aq), ionic substances break apart into component ions, so fewer bonds to rearrange

3. Define activation energy. How is the activation energy of a reaction like a wall or barrier?

- activation energy - amount of energy required to form the activated complex & start the rxn.
- Like a wall/barrier b/c it must be overcome in order for the reaction to occur.

4. How is the rate of a reaction influenced by a catalyst? How does a catalyst make this possible?

A catalyst ↑ the rate of a reaction by providing an alternate rxn pathway with a lower activation energy.

Practice Multiple Choice:

5. Which of the following reactions is likely to have the fastest reaction rate?

a. $Zn\ (s) + S\ (s) \rightarrow ZnS\ (s)$
b. $NaOH\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$ ← dissolved ionic will react fastest
c. $C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$
d. $CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$ ← not dissolved

6. Given the balanced equation representing a reaction:

$$Zn\ (s) + 2HCl\ (aq) \rightarrow H_2\ (g) + ZnCl_2\ (aq)$$

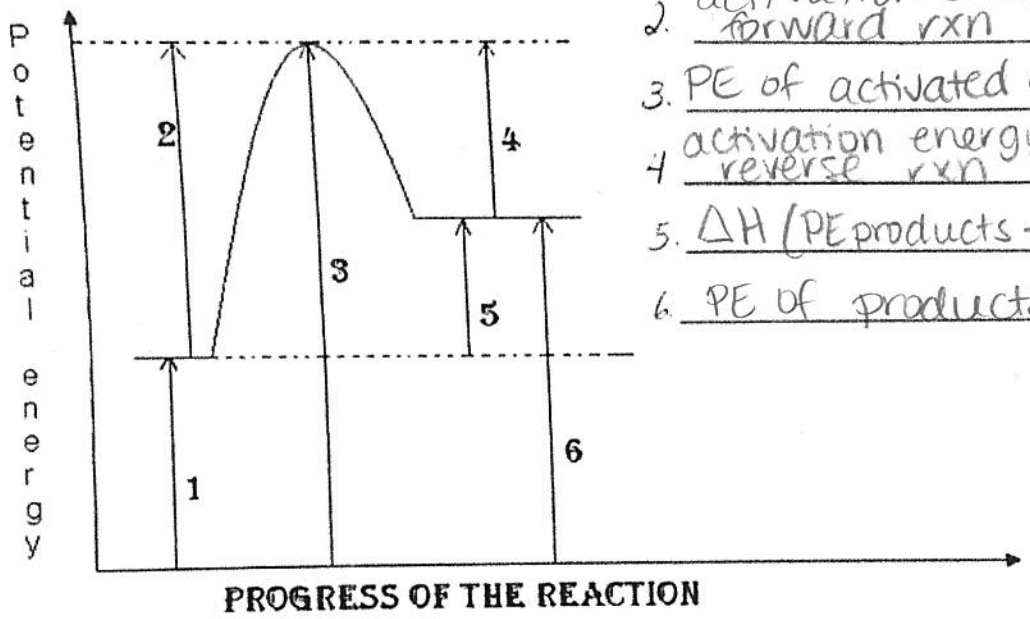
Which set of reaction conditions produces H_2 (g) at the fastest rate?

a. a 1.0-g lump of Zn (s) in 50. mL of 0.5 M HCl (aq) at 20.°C
b. a 1.0-g lump of Zn (s) in 50. mL of 0.5 M HCl (aq) at 30.°C
c. 1.0-g of powdered Zn (s) in 50. mL of 1.0 M HCl (aq) at 20.°C
d. 1.0-g of powdered Zn (s) in 50. mL of 1.0 M HCl (aq) at 30.°C

greater surface area; higher concentration; highest temperature

Station 2- Potential Energy Diagrams

1. Label the numbered segments on the following potential energy diagram:



1. PE of reactants
2. activation energy of forward rxn
3. PE of activated complex
4. activation energy of reverse rxn
5. ΔH (PE products - PE reactants)
6. PE of products

2. Which intervals on the diagram above will change with the addition of a catalyst?

2, 3, & 4

3. On the PE diagram above, draw a dashed lined to indicated how the reaction pathway would change with the addition of a catalyst.

lowers "hill"; won't change PE of reactants or products

4. a. According to the PE diagram above, is the forward reaction endothermic or exothermic? Justify your response.

endothermic b/c $PE_{products} > PE_{reactants}$

b. Based on your answer to part a, what sign would the ΔH of this reaction have? $+\Delta H$

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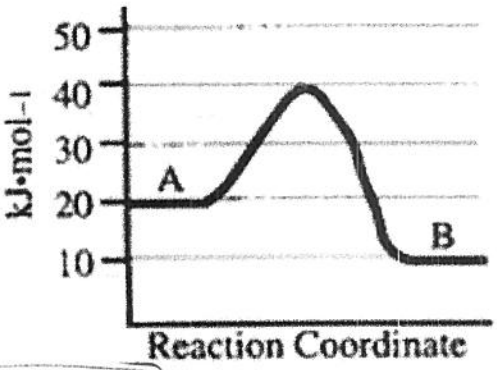
Base your answer to questions to questions 5-7 on the potential energy diagram pictured to the right.



5. What is the ΔH for the reaction A→B, represented by the potential energy diagram to the right?

a) +10 b) +30 c) -30 d) -20 e) -10

$PE_{products} - PE_{reactants} = 10 - 20 = -10$

6. What is the activation energy of the forward reaction?

$PE_{activated\ complex} - PE_{reactants} = 40 - 20 =$ 20 kJ

7. Would this reaction be classified as endothermic or exothermic? Support your answer using evidence from the potential energy diagram.

exothermic, b/c PE products > PE reactants

Station 3- Enthalpy/Heat of Reaction (ΔH)

1. Circle the correct word from each pair in parentheses to complete the sentences:
   a. A $-\Delta H$ means that the reaction is (endothermic/exothermic) and energy is (absorbed/released). When writing a thermochemical equation, the amount of energy should be written in the (reactants/products).

   b. A $+\Delta H$ means that the reaction is (endothermic/exothermic) and energy is (absorbed/released). When writing a thermochemical equation, the amount of energy should be written in the (reactants/products).

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Use Reference Table I to answer the following information:

Methane undergoes a combustion reaction as demonstrated by the balanced equation:

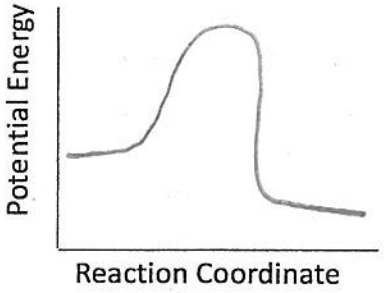
$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(l) \qquad \Delta H = -890.4\ kJ$$

↳ put into products

2. Write a *thermochemical equation* for the combustion of methane.

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

3. Decide if this reaction would be classified as endothermic or exothermic. Then, sketch a general potential energy diagram for this reaction on the axes to the right.



4. Determine the ΔH of the *reverse* reaction. $+890.4\ kJ$

5. Determine the ΔH of the reaction if 4 moles of H_2O (l) were produced.

$-890.4\ kJ \times 2 = \boxed{-1780.8\ kJ}$

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Use Reference Table I to answer the following information:

Nitrogen gas combines with oxygen gas to form nitrogen monoxide according to the following balanced equation:

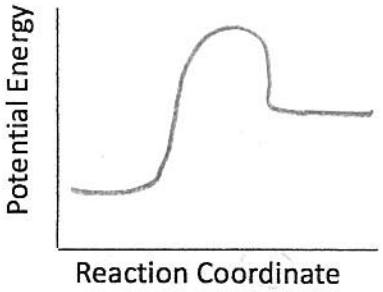
$$N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g) \qquad \Delta H = +182.6\ kJ$$

6. Write the *thermochemical equation* for the reaction above.

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

7. Decide if this reaction would be classified as endothermic or exothermic. Then, sketch a general potential energy diagram for this reaction on the axes to the right.

↳ b/c $+\Delta H$



8. Determine the ΔH of the *reverse reaction*.

$-182.6\ kJ$

9. Determine the ΔH of the reaction if 1 mole of NO (g) was produced.

$$\frac{+182.6}{2} = \boxed{91.3\ kJ}$$

Station 4- Entropy and Spontaneous Reactions

1. Circle the correct word from each pair in parentheses to complete the sentences:
   a. A $-\Delta S$ means that entropy is (increasing/ decreasing). Therefore, the system is going towards a more (ordered/ disordered) state.

   b. A $+\Delta S$ means that entropy is (increasing/ decreasing). Therefore, the system is going towards a more (ordered/ disordered) state.

2. Fill out the following table to review the factors affecting entropy.

Factor	Effect on Entropy
Phase of matter	*Rank the phases of matter from least entropy to most entropy:* solid < liquid < gas
Temperature	↑ temperature, ↑ entropy
Number of Particles	↑ # of particles, ↑ entropy
Creating a mixture/solution	A mixture/solution (look for aq) has ↑ entropy than its individual components.

3. Predict the sign of ΔS for each of the following:
   a. $CaCO_3$ (s) → CaO (s) + CO_2 (g): $+\Delta S$ Why? entropy ↑ b/c 1 particle → 2
   b. NH_3 (g) + HCl (g) → NH_4Cl (s): $-\Delta S$ Why? entropy ↓ b/c 2 → 1 & g → s
   c. NaCl (s) → Na^+ (aq) + Cl^- (aq): $+\Delta S$ Why? dissolving (aq)

4. Circle the system from each pair that has the lower entropy:
   a. Completed jigsaw puzzle OR separate jigsaw puzzle pieces
   b. 50 mL of liquid water OR 50 mL of ice
   c. 10 g of calcium chloride crystals OR a solution containing 10 g of calcium chloride

5. What does it mean if a reaction is said to be *spontaneous*?
   The reaction can occur on its own, without an external influencing force.

6. Under which conditions of enthalpy (ΔH) and entropy (ΔS) is a reaction *always* spontaneous?
   a. When the reaction is endothermic and entropy increases
   b. When the reaction is endothermic and entropy decreases
   c. When the reaction is exothermic and entropy increases — Think about what happens in life: your energy ↓ (exothermic) & your room gets messy (↑ entropy)
   d. When the reaction is exothermic and entropy decreases

7. What will the signs of ΔH and ΔS be for a reaction that is nonspontaneous?
   a. $+\Delta H, +\Delta S$ (endothermic $+\Delta H$)
   b. $-\Delta H, -\Delta S$ (↓ entropy $-\Delta S$)
   c. $+\Delta H, -\Delta S$
   d. $-\Delta H, +\Delta S$

Station 5- Equilibrium

Directions: Use the word bank provided to fill in the blanks in the following paragraph. Each term may be used once, more than once, or not at all.

Word Bank				
constant	equal	forward	reverse	reversible

A (1) reversible reaction is one that can proceed in both the forward and reverse reactions. In the (2) forward reaction, the reactant particles undergo collisions to create products. In the (3) reverse reaction, the product particles undergo collisions and create more reactants. Once equilibrium is reached, the rates of the forwards and reverse reactions are (4) equal. However, the concentrations of the reactants and products are (5) constant.

6. How are the terms *equal* and *constant* different?
   - equal means two things are the same as one another.
   - constant means something is staying the same/ not changing

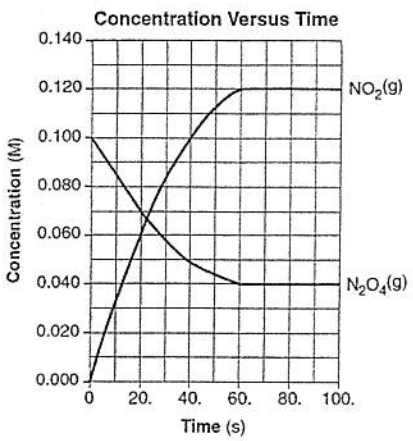
7. Given the phase equilibrium in a closed container: H_2O (g) ⇌ H_2O (l)
   Compared to the rate of gas formation, the rate of liquid formation is
   a. slower b. faster c. the same

8. Given the equation representing a system at equilibrium: 2 SO_2 (g) + O_2 (g) ⇌ 2 SO_3 (g)
   At equilibrium, the concentration of
   a. SO_2 (g) must equal the concentration of SO_3 (g)
   b. SO_2 (g) must be constant - constant concentrations @ equilibrium
   c. O_2 (g) must equal the concentration of SO_2 (g)
   d. O_2 (g) must be decreasing

9. Which quantities must be *equal* for a chemical reaction at equilibrium? - equal rates at equilibrium
   a. the activation energies of the forward and reverse reactions
   b. the rates of the forwards and reverse reactions
   c. the concentrations of the reactants and products
   d. the potential energies of the reactants and products

10. Which statement correctly describes a chemical reaction at equilibrium?
    a. the concentration of the products and reactants are equal
    b. the concentrations of the products and reactants are constant
    c. the rate of the forward reaction is less than the rate of the reverse reaction
    d. the rate of the forward reaction is greater than the rate of the reverse reaction

11. The graph to the right shows the concentration of reactants and products as the reversible reaction of N_2O_4 (g) ⇌ 2 NO_2 (g) progresses. After what time is the reaction at equilibrium? Provide evidence from the graph to support your answer.
    After 60 sec, b/c after that point, the concentrations of reactants & products are constant.



Station 6- LeChâtelier's Principle

Read This- When a chemical system that is already at equilibrium is disturbed, the system will shift in a direction that minimized the disturbance in order to restore equilibrium. This is known as LeChâtelier's Principle. "Add away, take towards"

1. Summarize the factors affecting equilibrium by circling the correct word from each pair in parentheses.

Change	Effect on Equilibrium
Increase in concentration	When the concentration of a substance is increased, the reaction will shift (away from/towards) that substance.
Decrease in concentration	When the concentration of a substance is decreased, the reaction will shift (away from/towards) that substance.
Increase in pressure	When pressure of a reaction increases, the reaction will shift towards the side of the reaction with (more/fewer) moles of gas particles.
Decrease in pressure	When pressure of a reaction decreases, the reaction will shift towards the side of the reaction with (more/fewer) moles of gas particles.
Increase in temperature	When temperature increases, the reaction will shift (away from/towards) the side of the reaction with the heat.
Decrease in temperature	When temperature decreases, the reaction will shift (away from/towards) the side of the reaction with the heat.

2. What effect do each of the following changes have on the equilibrium position for this reversible reaction?

$$\underset{1}{PCl_5\,(g)} + \text{heat} \rightleftharpoons \underset{2}{PCl_3\,(g)} + Cl_2\,(g)$$

a) Addition of Cl_2: shift left
b) Increase in pressure: shift left
c) Removal of heat: shift left
d) Removal of PCl_3: shift right

3. Given the reaction at equilibrium: $N_2\,(g) + 3\,H_2\,(g) \rightleftharpoons 2\,NH_3\,(g) + 91.8\text{ kJ}$
What occurs when the concentration of H_2 is increased? ← shift left!
   a. The rate of the forward reaction increases and the concentration of N_2 (g) decreases
   b. The rate of the forward reaction decreases and the concentration of N_2 (g) increases
   c. The rate of the forwards reaction and the concentration of N_2 (g) both increase
   d. The rate of the forwards reaction and the concentration of N_2 (g) both decrease

4. Given the reaction at equilibrium: $A\,(g) + B\,(g) \rightleftharpoons C\,(g) + D\,(g)$
The addition of a catalyst will
   a. Shift the equilibrium to the right
   b. Shift the equilibrium to the left
   c. Increase the rate of the forward *and* reverse reactions
   d. Have no effect on the forward or reverse reactions