

KC- Kinetics and Thermodynamics Test Review Stations

Koen

Station 1- Collision Theory and Factors Affecting Reaction Rate

1. Explain the collision theory of reactions.

In order for a chemical rxn to occur, reactant particles must collide with sufficient kinetic energy and 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 & with greater kinetic energy |
| Concentration | ↑ concentration, ↑ rate | w/ 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, ionic substances break apart into component ions, so fewer bonds to rearrange, & rxn will require less energy. |

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.

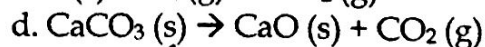
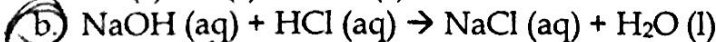
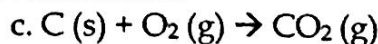
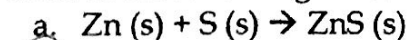
• Like a wall/barrier, b/c it must be overcome in order for the reaction to occur.

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

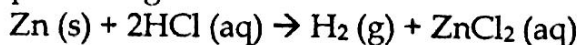
A catalyst increases the rate of a reaction by providing an alternate reaction pathway with a lower activation energy.

Practice Multiple Choice:

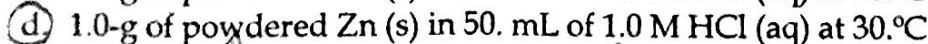
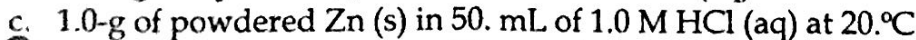
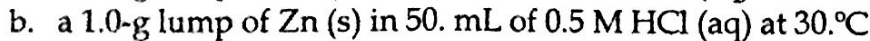
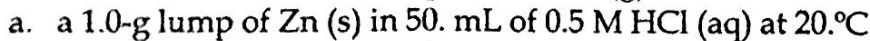
5. Which of the following reactions is likely to have the fastest reaction rate?



6. Given the balanced equation representing a reaction:



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



greater surface area

higher concentration

higher temp.

Station 2- Reaction Mechanisms

A reaction mechanism is the series of steps by which substances react. The slowest step in the series is the rate-determining step. Changes in concentration of a substance can change the rate of a reaction only if the substance is involved in the rate-determining step.

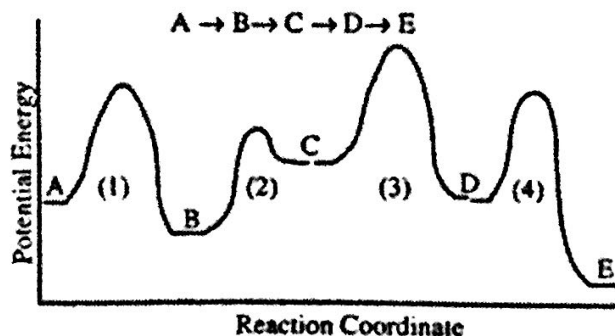
Answer the following questions given the following reaction mechanism:



1. Write the overall reaction: $A + F \rightarrow D + E$
2. Identify the intermediate: C
 - a. How did you determine that this is the intermediate?
It is a product in an earlier step & a reactant in a later step.
3. Identify the catalyst: B_2
 - a. How did you determine that this is the catalyst?
It is a reactant in an earlier step and a product in a later step, showing that it is regenerated.
4. Which step is considered the rate-determining step?
Step 1 (the "slow" step)
5. What will be the effect on the reaction rate if the concentration of A is increased? Why?
The rxn rate will \uparrow because A is a reactant in the rate-determining step.
6. What will be the effect on the reaction rate if the concentration of F is increased? Why?
No effect, b/c F is not in the rate-determining step.

7. Which is the rate-determining step for this hypothetical reaction mechanism of the reaction $A \rightarrow E$?

3 - it has the greatest activation energy

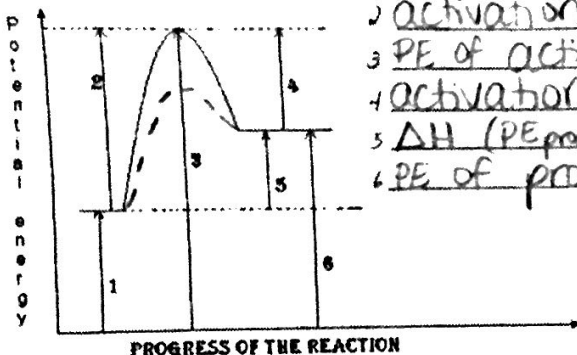


8. Fill in the blank:

As activation energy increases, rate of a chemical reaction decreases
(takes a longer time)

Station 3- Potential Energy Diagrams and Internal Energy

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 ($PE_{\text{products}} - PE_{\text{reactants}}$)
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.

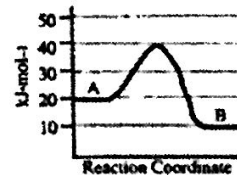
lowers "hill," won't change PE of reactants or products

4. a. According to the PE diagram above, is the forward reaction endothermic or exothermic? Justify your response. endothermic b/c $PE_{\text{products}} > PE_{\text{reactants}}$

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

5. What is the ΔH for the reaction $A \rightarrow B$, represented by the potential energy diagram to the right? $PE_{\text{products}} - PE_{\text{reactants}} = 10 - 20$

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



Internal Energy

Equation for calculating ΔU :

$$\Delta U = q + w$$

6. Circle the correct word from each pair in parentheses to complete the sentences:

a. In the equation for ΔU , q stands for (work/heat). If the system absorbs energy from its surroundings, q will be (negative/positive). If the system releases energy to its surroundings, q will be (negative/positive).

b. In the equation for ΔU , w stands for (work/heat). If the system does work on its surroundings, w will be (negative/positive). If the surroundings do work on the system, w will be (negative/positive).

7. A system absorbed 250. kJ of energy from its surroundings and the surroundings did 615 kJ of work on the system. Calculate the change in internal energy, in kJ.

$$\begin{aligned} \Delta U &= q + w \\ &= +250 \text{ kJ} + 615 \text{ kJ} \\ &= \boxed{865 \text{ kJ}} \end{aligned}$$

$$w = +615 \text{ kJ}$$

Station 4- Enthalpy

Equation for calculating ΔH_{rxn} :

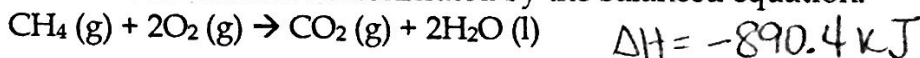
$$\Delta H_{rxn} = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

8. Circle the correct word from each pair in parentheses to complete the sentences:

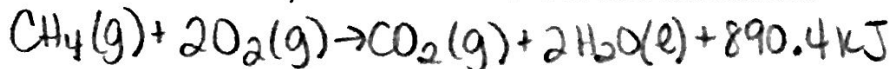
- a. A $-\Delta H_{rxn}$ means that the reaction is (endothermic/exothermic) and energy is (absorbed/released). When writing a thermochemical equation, the amount of energy should be written in the (reactants/products).
- b. A $+\Delta H_{rxn}$ means that the reaction is (endothermic/ exothermic) and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

Use Reference Table I to answer the following information:

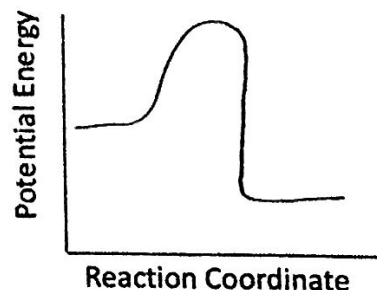
Methane undergoes a combustion reaction as demonstrated by the balanced equation:



9. Write a thermochemical equation for the combustion of methane.



10. 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.

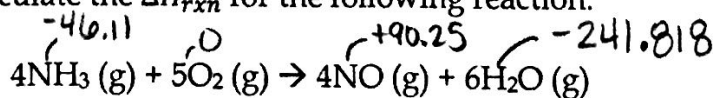


11. Determine the ΔH of the reverse reaction. $+890.4 \text{ kJ}$

12. Determine the ΔH of the reaction if 4 moles of $\text{H}_2\text{O}(\text{l})$ were produced.

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

13. Use Table A-6 to calculate the ΔH_{rxn} for the following reaction:



$$\begin{aligned} \Delta H_{rxn} &= \sum H_f^\circ \text{ products} - \sum H_f^\circ \text{ reactants} \\ &= \left[(4 \cdot 90.25) + (6 \cdot -241.818) \right] - (4 \cdot -46.11) \\ &= \boxed{-905.468 \text{ kJ}} \end{aligned}$$

Station 5- Entropy

Equation for calculating ΔS_{rxn} :

$$\Delta S_{rxn} = \sum S^{\circ}_{\text{products}} - \sum S^{\circ}_{\text{reactants}}$$

- Circle the correct word from each pair in parentheses to complete the sentences:
 - A $-\Delta S_{rxn}$ means that entropy is (increasing/decreasing). Therefore, the system is going towards a more (ordered/disordered) state.
 - A $+\Delta S_{rxn}$ 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 | As temp \uparrow , entropy \uparrow b/c particles move around more randomly. |
| Number of Particles | More particles = \uparrow entropy fewer particles = \downarrow entropy |
| Creating a mixture/solution | A mixture/solution has greater entropy than its individual component parts |

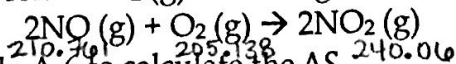
3. Predict the sign of ΔS for each of the following:

- $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$: $+\Delta S$ Why? $1 \rightarrow 2$ particles & $\text{s} \rightarrow \text{g}$
- $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$: $-\Delta S$ Why? $2 \rightarrow 1$ particle & $\text{g} \rightarrow \text{s}$
- $\text{NaCl}(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$: $+\Delta S$ Why? creating a solution

4. Circle the system from each pair that has the lower entropy:

- Completed jigsaw puzzle OR separate jigsaw puzzle pieces
- 50 mL of liquid water OR 50 mL of ice
- 10 g of calcium chloride (solid) crystals OR a solution containing 10 g of calcium chloride

5. NO (g) reacts with O₂ (g) to form NO₂ (g) according to the balanced equation:



Use the information on Table A-6 to calculate the ΔS_{rxn} .

$$\Delta S_{rxn} = \sum S_{\text{products}} - \sum S_{\text{reactants}}$$

$$= (2 \cdot 240.06) - [(2 \cdot 210.761) + (205.138)]$$

$$= \boxed{-146.57}$$

Station 6-
Spontaneous
Reactions and Free
Energy

Equation for calculating ΔG_{rxn} : $\Delta G = \Delta H - (T \cdot \Delta S)$

*Unit for T must be in Kelvin !

- Circle the correct word from each pair in parentheses to complete the sentences:
 - A $-\Delta G_{rxn}$ means that the reaction is (spontaneous/nonspontaneous). The reaction can therefore be classified as (endergonic/exergonic).
 - A $+\Delta G_{rxn}$ means that the reaction is (spontaneous/nonspontaneous). The reaction can therefore be classified as (endergonic/exergonic).
- Under which conditions of enthalpy (ΔH) and entropy (ΔS) is a reaction *always* spontaneous?
 - When the reaction is endothermic and entropy increases
 - When the reaction is endothermic and entropy decreases
 - When the reaction is exothermic and entropy increases
 - When the reaction is exothermic and entropy decreases
- Evaluate the following two statements:

F I. An exothermic reaction is always a spontaneous reaction
BECAUSE

T II. Exothermic reactions release heat to the surroundings.

also depends on ΔS .

 - I is TRUE, II is FALSE
 - I is FALSE, II is TRUE
 - I and II are BOTH FALSE
 - I and II are BOTH TRUE but II IS NOT a correct explanation of I
 - I and II are BOTH TRUE and II IS a correct explanation of I
- For the decomposition of CaCO_3 (s) to CaO (s) and CO_2 (g) at 298 K the ΔH_{rxn} is 178.5 kJ/mol and the ΔS_{rxn} is 161.6 J/K·mol. Calculate the free energy change of the reaction, then state if the reaction is spontaneous or nonspontaneous at this temperature.

change ΔS
to kJ
= 0.1616 kJ/mol

$$\Delta G = \Delta H - (T \cdot \Delta S)$$

$$\Delta G = 178.5 - (298 \cdot 0.1616)$$

$$\Delta G = \boxed{+130.3432} \rightarrow \text{nonspontaneous}$$

Find the following reactions in Table I. In the table below list the value for ΔH . Examine the reaction and estimate whether ΔS is positive, negative, or zero (no change). State whether the reaction will *always occur*, *never occur*, *occur only at high temperatures*, or *only occur at low temperatures*.

| Reaction | ΔH (kJ) | ΔS | will occur |
|---|-----------------|------------|------------------------------|
| example) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$ | -91.8 | (-) | only @ low temps |
| 5. $\text{Li}^+(\text{aq}) + \text{Br}^-(\text{aq}) \rightarrow \text{LiBr}(\text{s})$ <small>reverse Table I</small> | +48.83 | - | never occur |
| 6. $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$ | -2804 | + | always occur |
| 7. $\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{NO}_3^-(\text{aq})$ | +25.69 | + | will only occur @ high temps |