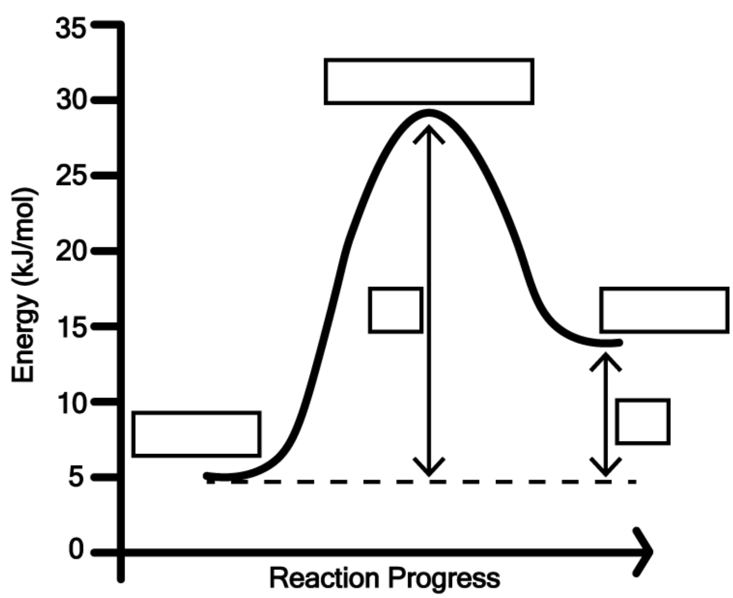
Kinetics Part 1

Chapter 17-1 to 17-3: Reaction Profiles, Reaction Rates, and Experimental Rate Laws

Have you ever seen how much energy is in a sugar cube? This may seem like an odd question (though you will “see” how much chemical energy is released during combustion of a sugar cube soon!), but it offers some interesting insights about chemical reactions. There is a great deal of chemical energy stored within sugars, which is one of the reasons why they are so effective at giving us energy. However, we do not want all that energy being released at once inside our bodies (it wouldn’t be pretty), rather, we want the energy to be gradually released. This is one of the many reasons why we as scientists are interested in the speeds of reactions, or *chemical kinetics.* This worksheet will help you get acquainted with reaction rates, rate laws, and important entities known as rate constants.

1. Reaction Coordinate Diagrams!

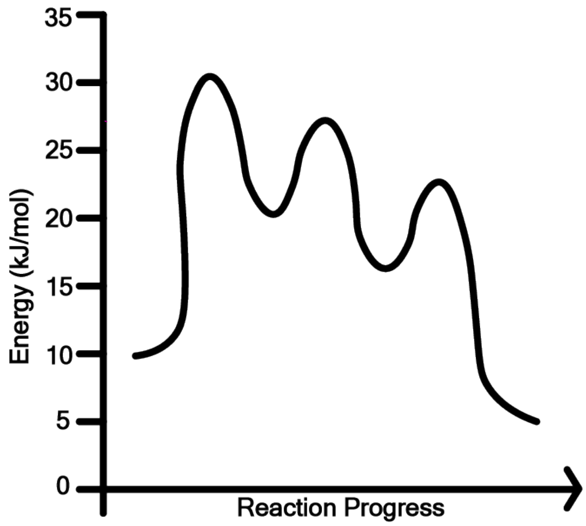
a. For the following reaction coordinate diagram, identify how many steps there are for the reaction. Classify the reaction as endothermic or exothermic. Label the transition state/activated complex, reactants, products, E_a, and ΔE.



b. Utilizing the y-axis, calculate the activation energy (E_a) and ΔE for the **FORWARD** reaction using the reaction coordinate diagram above.

c. Utilizing the y-axis, calculate the activation energy (E_a) and ΔE for the **REVERSE** reaction using the reaction coordinate diagram above.

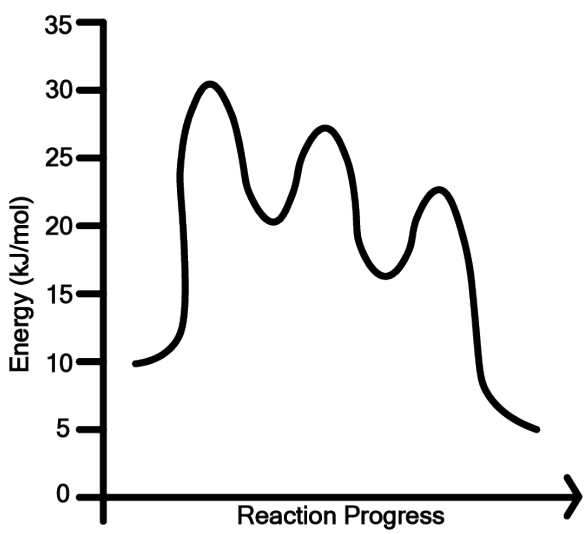
2. Alright, let's do one more but a tad more complex (You got this!). For the following reaction coordinate diagram, identify how many steps there are for the reaction. Classify the reaction as endothermic or exothermic. Label ALL the transition states/activated complexes, reactants, products, intermediates, E_a, and ΔE (You do not need to calculate the energies unless you feel inclined).



a. What is the **FASTEST** step using the reaction coordinate diagram above? Why?

b. What is the **SLOWEST/** rate-limiting step using the reaction coordinate diagram above? Why?

1. c. Label the activation energies of the REVERSE reaction (You do not need to calculate the energies unless you feel inclined).



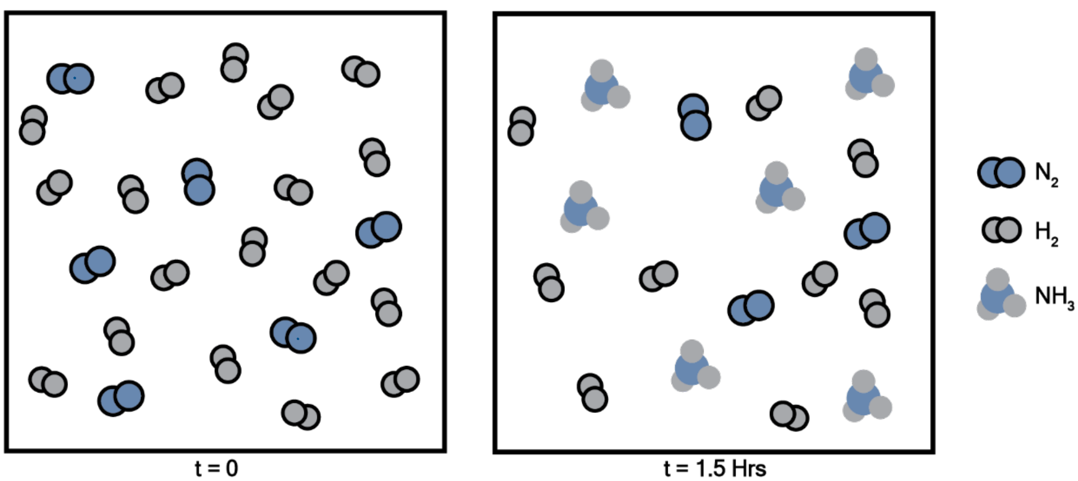
2. The Haber process is an industrial procedure that synthesizes ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2) gases:

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

FUN FACT: The Haber process was first developed by Fritz Haber and Carl Bosch in the early 1900s as an easier means of producing ammonia for fertilizer and were awarded the Nobel Prize in 1918 and 1931 for this work. During the WWI era, the process was used to make explosives. Even today, the Haber process is still relevant and produces more than 450 million TONS of nitrogen fertilizer every year! We will be using this reaction consistently throughout the semester (along with some other cool ones)!

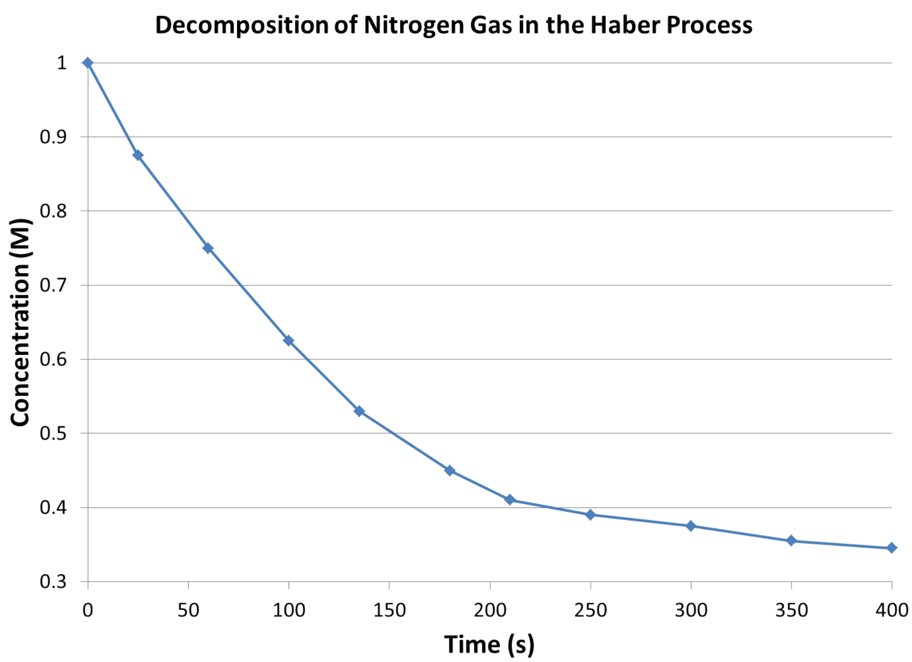
a. Please write an expression to relate the rate of disappearance of reactants (N_2 and H_2) to the rate of appearance of products (NH_3):

b. Using the equation you made above, calculate the AVERAGE RATE of disappearance of N_2 (g) given the figure below? Each N_2, H_2, and NH_3 molecule depicted below represents a concentration of 1M. ***DON'T FORGET UNITS***



c. If at a particular factory the initial **instantaneous rate** of consumption of H_2 (g) is 2.4 M/s, what is the rate of production of NH_3? (HINT: Use your equation from 3a and look at the molar ratios)

d. What is the difference between AVERAGE RATE and INSTANTANEOUS RATE? Use the graph below to indicate the differences. Which one is better for reporting the rates of chemical reactions? Why?



e. An ambitious scientist performed the Haber process at 450°C and repeated the experiment 2 additional times with different starting concentrations of reactants.

Experiment #	[H_2] (M)	[N_2] (M)	Rate (M / s)
1	1.2	1.2	2.4×10^{-3}
2	2.4	1.2	4.8×10^{-3}
3	1.2	2.4	9.6×10^{-3}

- What is the order of the reaction in respect to H_2?

- What is the order of the reaction in respect to N_2?

- What is the overall Rate Law? Overall Order?

f. Calculate the rate constant, k, using the Rate Law you found above. What are the units of the rate constant?

g. What would the reaction rate be under the same conditions but with the different reactant concentrations given below? What are the units of the reaction rate?

[H_2] = 4.8 M
[N_2] = 2.2 M

GROUP ACTIVITY

NAMES: ____

ACCESS IDS: ____

(such as abc12@psu.edu, NOT your 9 digit number)

Instructions:

- In a group of 4 or less, complete all parts of the following activity.
- You may finish outside of class.
- Please write legibly or we can't give you full credit.
- Every member needs to submit **their own copy** to Canvas by **11:59 PM** the day of your assigned Recitation.

Question 1: Now it's your turn! We will be working with plenty of graphs and diagrams this semester so let's familiarize ourselves with the **Reaction Coordinate Diagram**.

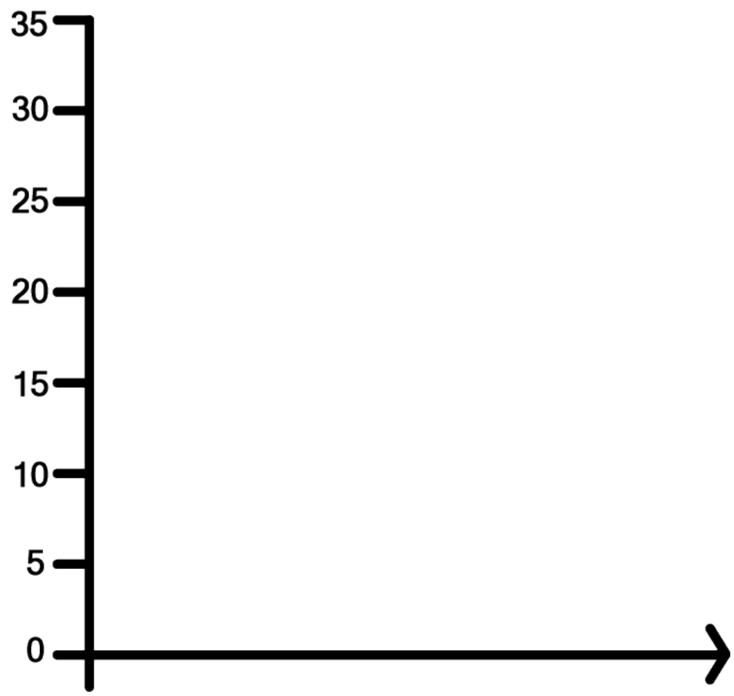
Given the description boxed below:

A TWO step, **exothermic** reaction with the rate limiting step being the FIRST step.

Label the axes (with units when appropriate), draw the reaction curve, and label the transition states/activated complexes, reactants, products, intermediate(s), E_a, and ΔE:

Is ΔE negative or positive?

Is E_a negative or positive?



*YOU **DO NOT** NEED TO CALCULATE VALUES for E_a AND ΔE but do draw the lines representing these values*

HINT: Review Problem 1 and its diagram