

Activities to Learn Concepts and Practice Skills Taught in Class

1. **Doing practice problems in small groups** – After teaching students about a particular skill or concept, ask them to spend five minutes working to solve a practice problem, or a question from last year's problem set, in groups of three students. Students can work at their tables or up at blackboards, and you can collect their answers through a multiple-choice poll or by asking for a volunteer to be ready to share the answers from each group.

Example question: Multiplicity (leave your answers in factorial terms):

(a) In a 7-by-7 grid space, what is the positional multiplicity of 3 molecules of A?

(b) In the same system, what is the multiplicity after adding 3 molecules of B? What about adding 3 molecules of A instead of B?

Example question: Multiplicity (leave your answers in factorial terms):

(a) In a 7-by-7 grid space, what is the positional multiplicity of 3 molecules of A?

Answer:

$$W(49,3) = \frac{49!}{3!46!}$$

(b) In the same system, what is the multiplicity after adding 3 molecules of B? What about adding 3 molecules of A instead of B?

Answer for adding 3B:

$$W(49,3,3) = \frac{49!}{3!3!43!}$$

Answer for adding 3 more A:

$$W(49,6) = \frac{49!}{6!43!}$$

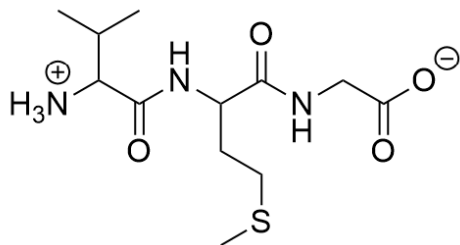
2. **Statement correction, or intentional mistakes** – The instructor provides statements, readings, proofs, or other material that contains errors. The students are charged with finding and correcting the errors. Concepts that students commonly misunderstand are well suited for this activity.

Example #1 question: Determine whether each statement is correct as written. Some of them are mostly correct and some are completely wrong. If a statement has an incorrect portion, write a more concise, accurate, and complete sentence.

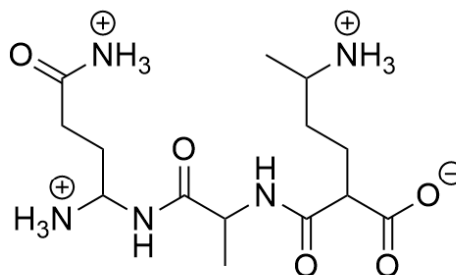
- (a) A spontaneous reaction means that the reaction can occur without the input of additional energy.
- (b) At equilibrium, the chemical reactions in both directions stop.
- (c) The more spontaneous a reaction (ie, the lower ΔG_{rxn}), the faster it happens.

Example #2 question: Identify the appropriately drawn peptide(s). For each correctly drawn peptide, write out its sequence using the three-letter amino acid code. If the peptide is drawn incorrectly, identify the errors and correct them.

(a)



(b)



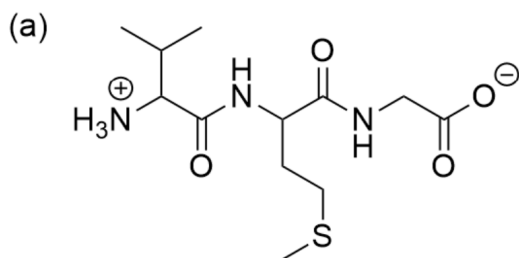
Example #1 answer: Determine whether each statement is correct as written. Some of them are mostly correct and some are completely wrong. If a statement has an incorrect portion, write a more concise, accurate, and complete sentence.

(a) A spontaneous reaction means that the reaction can occur without the input of additional energy.
This statement is correct.

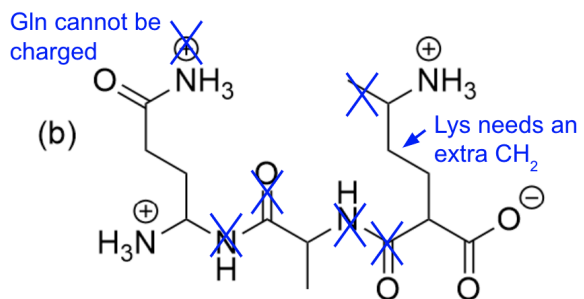
(b) At equilibrium, the chemical reactions in both directions stop.
This sentence is incorrect; at equilibrium the "forward" chemical reaction converting reactants to products and the "reverse" reaction converting products to reactants occur at the same rate.

(c) The more spontaneous a reaction (ie, the lower ΔG_{rxn}), the faster it happens.
This statement is incorrect. Spontaneity is unrelated to the speed of the reaction.

Example #2 answer: Identify the appropriately drawn peptide(s). For each correctly drawn peptide, write out its sequence using the three-letter amino acid code. If the peptide is drawn incorrectly, identify the errors and correct them.



Correct: Val-Met-Gly



Incorrect: several NH and CO groups in the backbone are flipped, and the Gln and Lys side chains are drawn in appropriately.

3. **Strip sequence, or sequence reconstruction** – The goal of this activity is for students to order a set of items that have a logical order, such as steps in a process, a series of historical events, or logical steps in an argument. As one strategy, the instructor provides students with a list of items written on strips of paper for the students to sort. An instructor can also leave one step “blank” and require that students fill it in. Removable labels with printed items also work well for this activity.

Example #1 question: You will be given six phrases which are the beginning, middle, and end of two separate sentences. Using your understanding of the Henderson-Hasselbalch equation, use these six phrases to generate two factually correct sentences.

Given a scenario in which an acid (“HA”) has been dissolved in water....

Example #2 question: You will be given cutouts of ribosomes in various stages during translation.

(1) Arrange the cutouts of the ribosome in the correct order.

(2) On image (A), indicate the region on the messenger RNA transcript which corresponds to both the red and yellow codons.

(3) What is the color of the amino-terminal amino acid?

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Given a scenario in which an acid (“HA”) has been dissolved in water....

“If the pH of the solution increases by 1 unit, then ...”

“...[H₃O⁺] goes down 10-fold and the solution gets more basic, and ...”

“...the ratio of [HA] (“protonated”) to [A⁻] (“deprotonated”) decreases by 10-fold.”

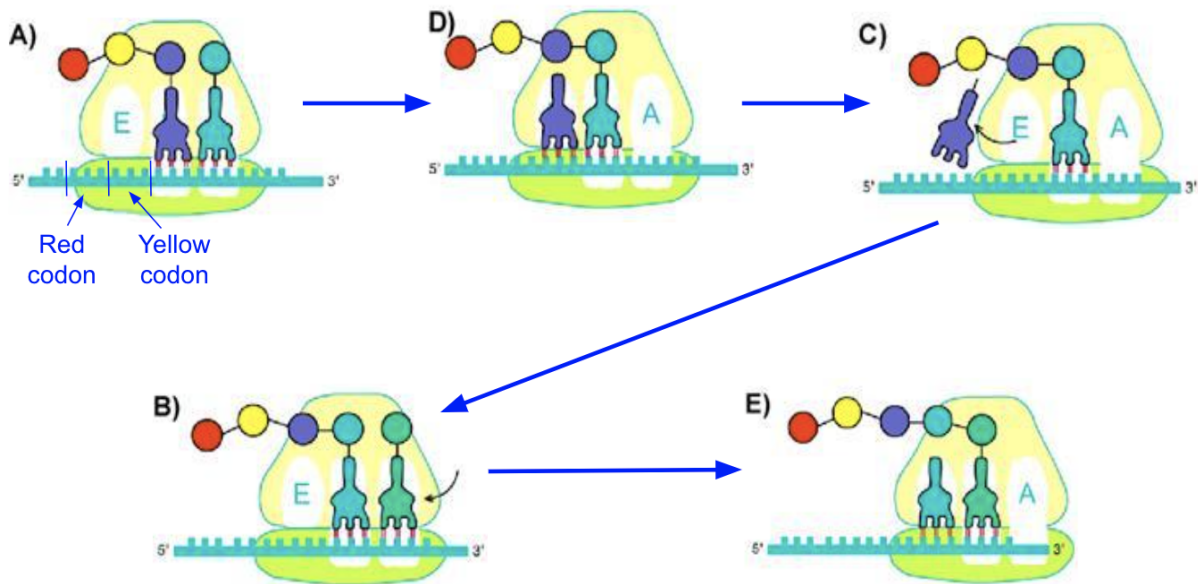
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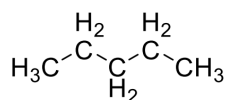
(2) On image (A), indicate the region on the messenger RNA transcript which corresponds to both the red and yellow codons.

(3) What is the color of the amino-terminal amino acid? **Red**

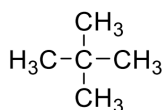
Activities to Increase Student Involvement, Engagement, and Inclusion

1. **Minute paper, or quick write** – Students write a short answer in response to a prompt during class, requiring students to articulate their knowledge or apply it to a new situation. For example, after asking your students a question, explicitly require them all to write out one, two, or three ideas that would capture their initial thoughts on how to answer the question posed. This act of writing itself may even lead students to discover points of confusion or key insights, and it can often provide students the time to build up the confidence to share their thoughts in an open group discussion.
2. **Think-pair-share** – 1) Students are asked to think about a question on their own, and perhaps respond in writing. 2) Students discuss their thoughts in pairs or small groups. 3) Individuals share their answers or ideas with the full class. Think-pair-share gives students the opportunity to calibrate their thinking with a peer before a group discussion, making them more likely to be willing to share their thoughts in front of the whole class.
3. **Anonymous Cards** – Students write questions about course material on index cards, which are distributed to other students. Each student researches the question that they received, and then shares what they have learned with the rest of the class.
4. **Brainstorm** – Students call out answers to an open-ended, creative question as the instructor or another student records the ideas on the board. Questions that can have many correct answers can encourage multiple students to engage.
5. **Polling** – During class, the instructor asks a multiple-choice question. Students can respond in a variety of ways. Students can respond to a multiple-choice question by raising the appropriate number of fingers or by holding up a colored card, where colors correspond to the different answers.

Example polling question: Shown below are the structures of two molecules, both of which contain the same number of carbon and hydrogen atoms.



n-pentane



neo-pentane



Based on the structures of these molecules, which of the following statements do you believe is true?

- (a) The boiling point of *n*-pentane is lower than the boiling point of *neo*-pentane.
(b) The boiling point of *n*-pentane is higher than the boiling point of *neo*-pentane
 (c) *n*-pentane and *neo*-pentane have the same boiling points.

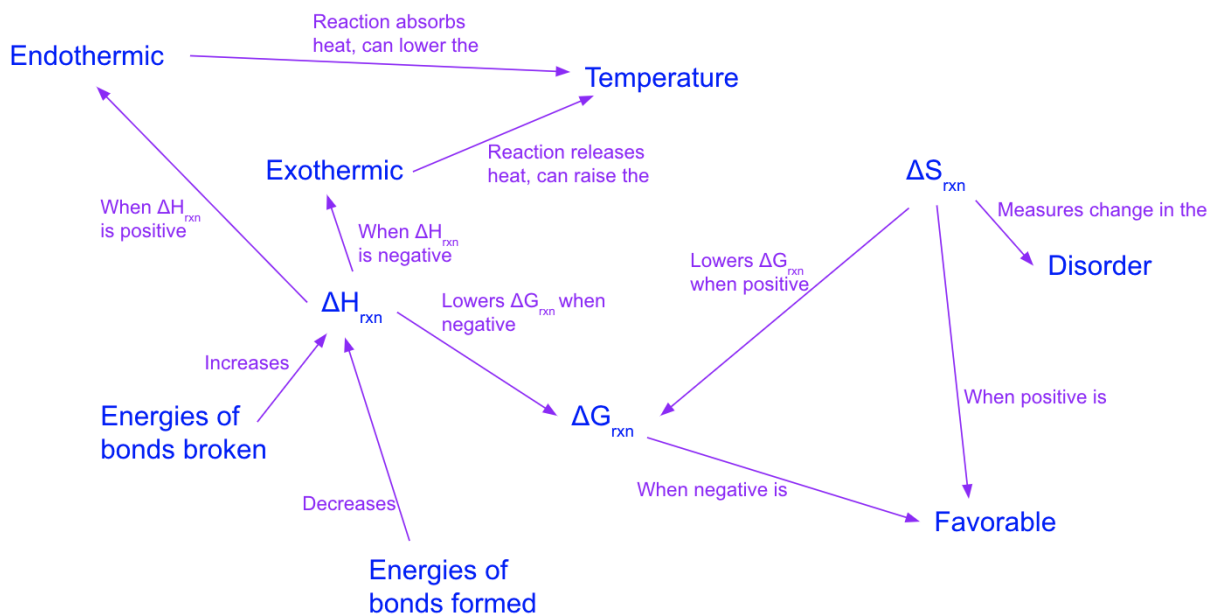
Examples of Activities to Help Students Synthesize and Review a Week's Worth of Content

1. **Concept map** – This activity helps students understand the relationship between concepts. Typically, students are provided with a list of terms. They arrange the terms on paper and draw arrows between related concepts, labeling each arrow to explain the relationship.

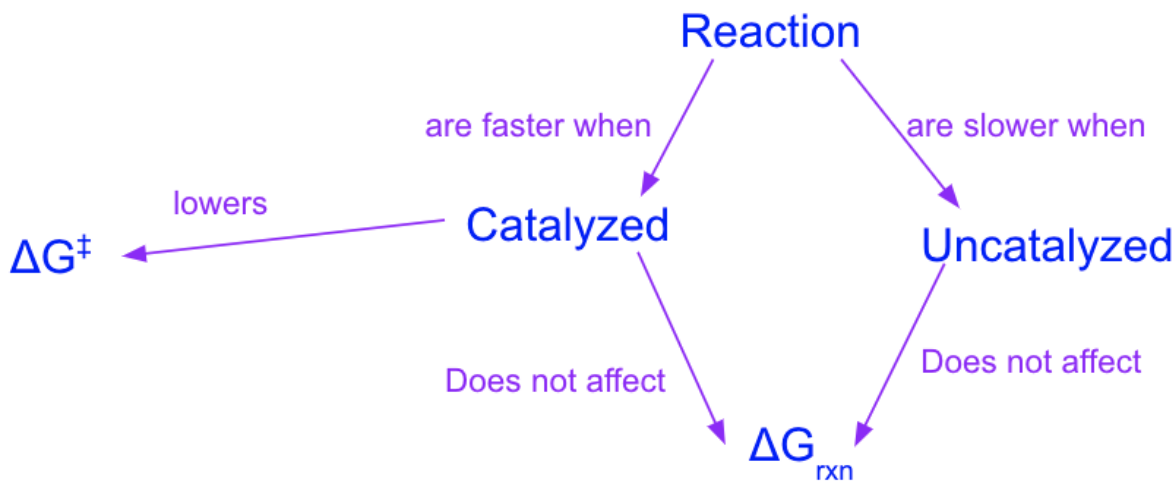
Example #1 question: Draw a concept map that shows the relationships between the following terms: " ΔG_{rxn} ," " ΔH_{rxn} ," " ΔS_{rxn} ," "temperature," "disorder," "exothermic," "endothermic," "favorable," "energies of bonds formed," and "energies of bonds broken."

Example #2 question: Draw a concept map that shows the relationships between the following set of terms: "reaction," "catalyzed," "uncatalyzed," " ΔG_{rxn} ," and " ΔG^\ddagger ."

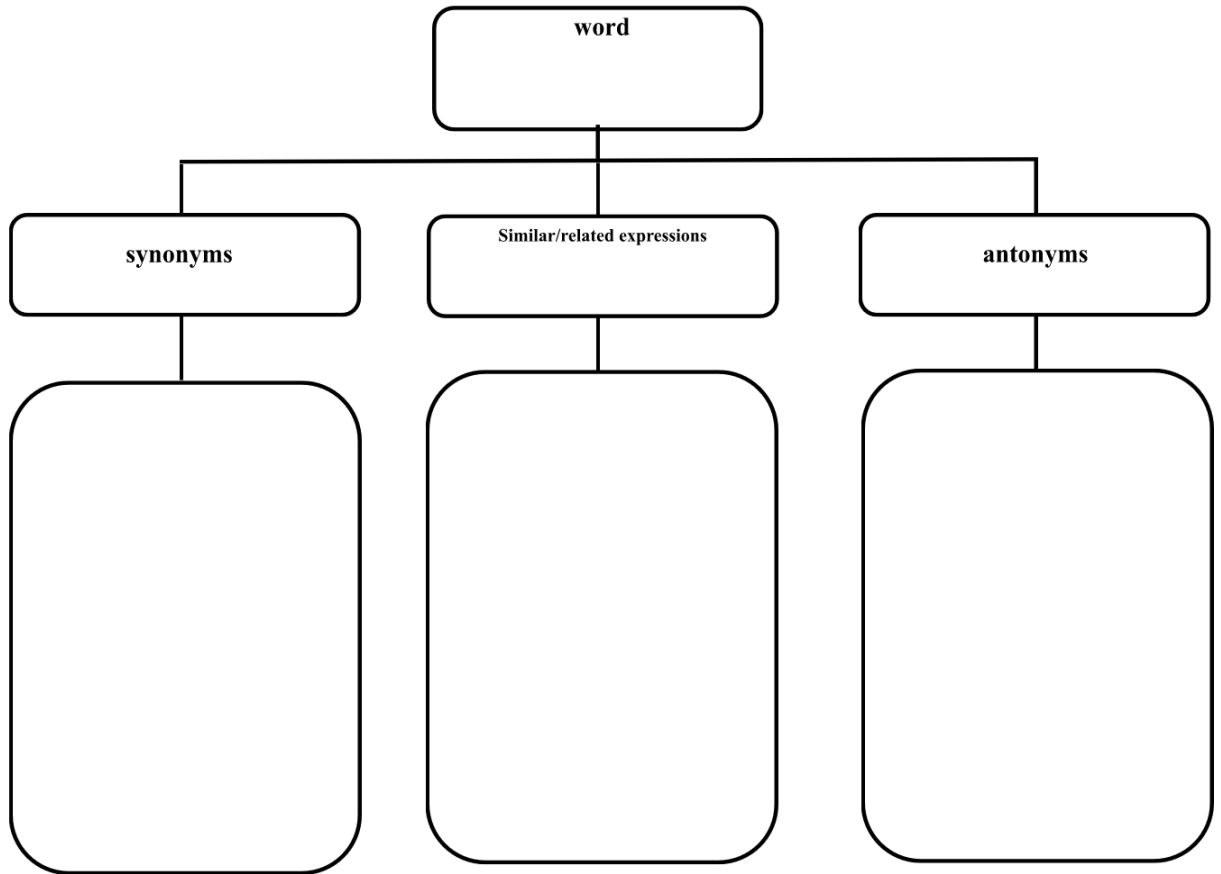
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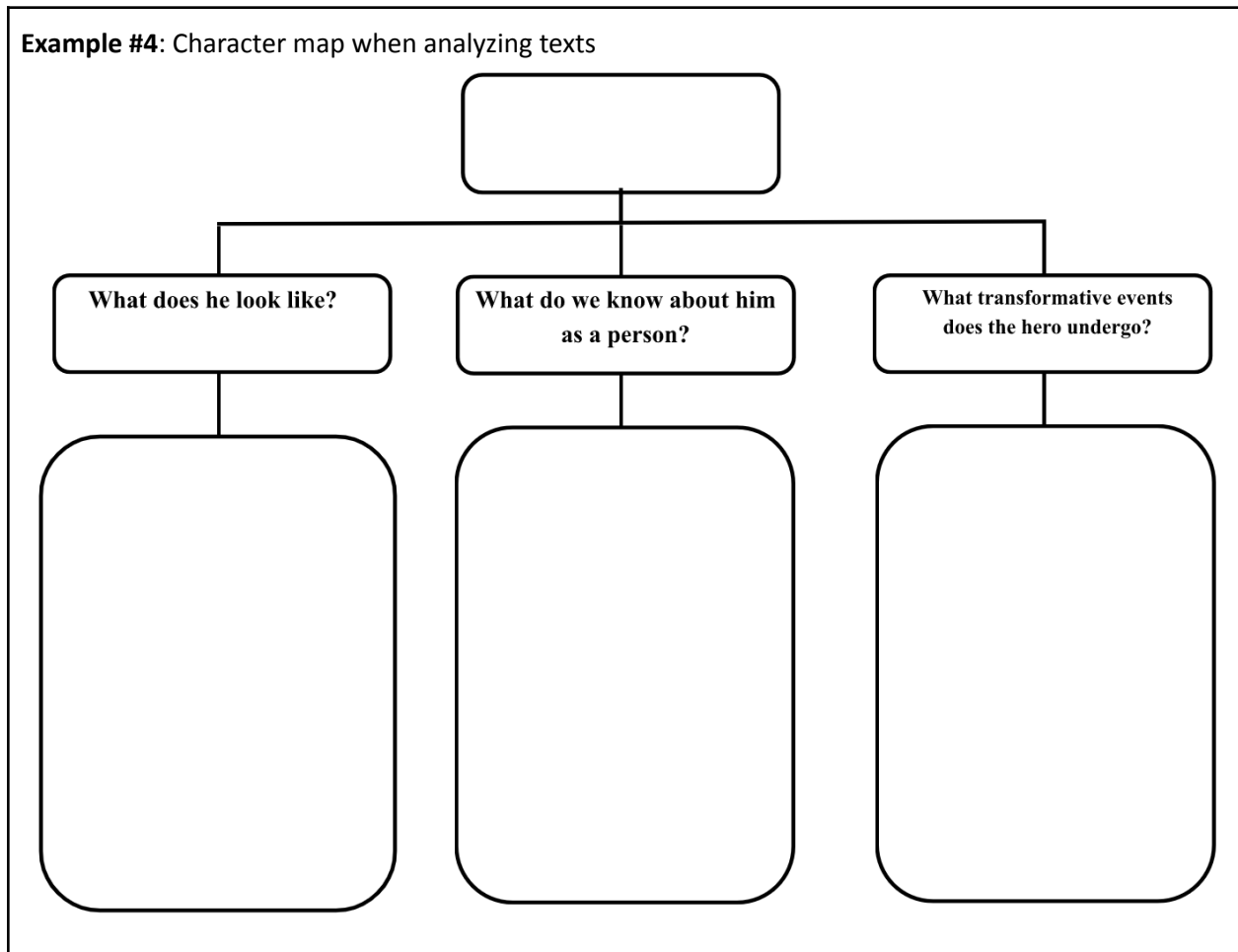
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Example #3: Word map to build vocabulary

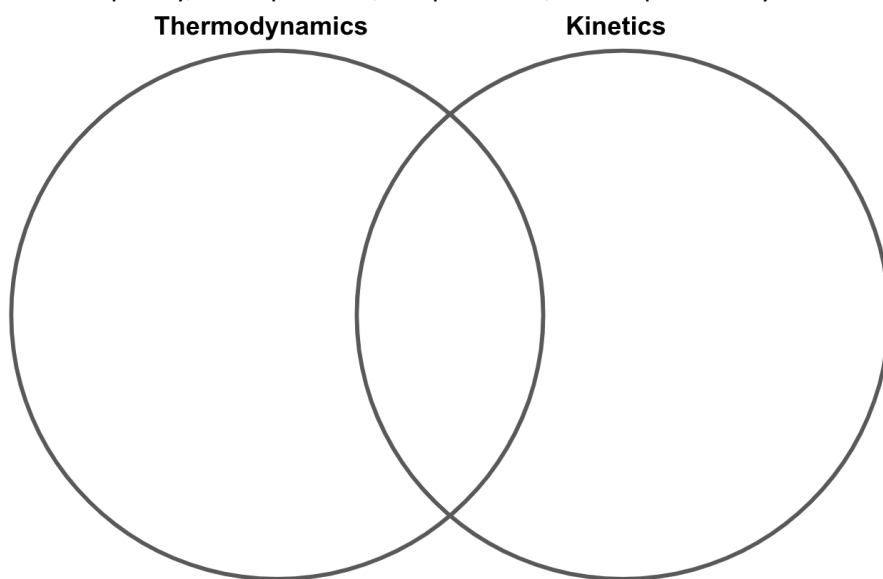


Example #4: Character map when analyzing texts

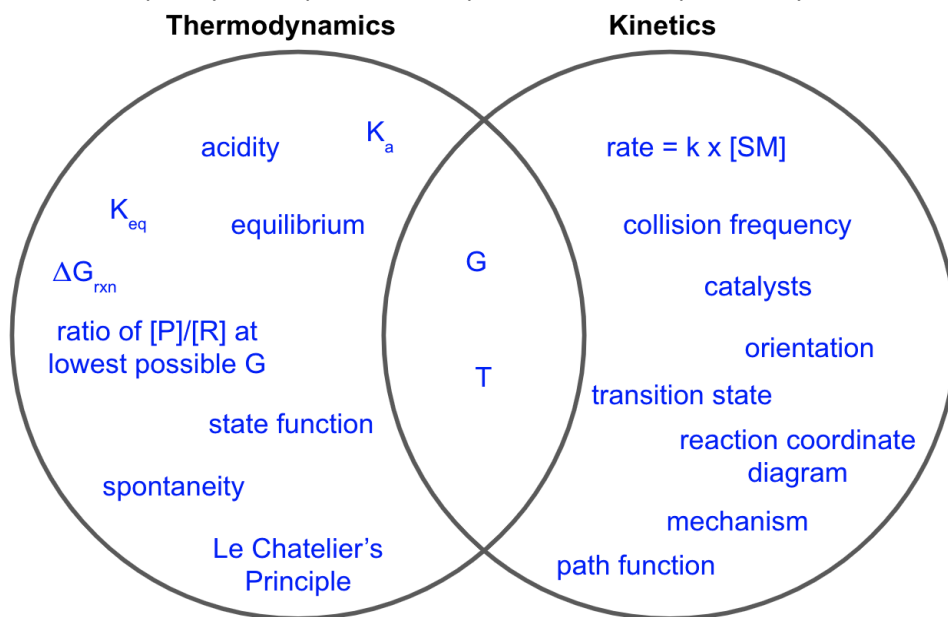


2. **Venn Diagram** – A diagram representing logical sets pictorially as circles or closed curves, with common elements of the sets being represented by the areas of overlap among the circles.

Example #1 question: Fill in the Venn diagram below relating thermodynamic and kinetic concepts. Use the following words and at least two others of your own: “ ΔG_{rxn} ,” “rate = $k \times [\text{SM}]$,” “G (Gibbs energy),” “collision frequency,” “temperature,” “equilibrium,” and “spontaneity.”



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3. Compare and Contrast – We often learn best by identifying differences between two examples. Asking students to find the similarities and differences between two theories, methods, objects, data sets, etc., can help students identify the distinguishing criteria that experts in a discipline use to organize and categorize information. Activities that prompt students to find the similarities and differences between two related concepts, skills, facts, theories, or objects help students learn both how the topics in question are superficially different (or similar) and motivates a deeper understanding of why these differences (or similarities) matter.

Cutouts for sequence reconstruction activities:

“If the pH of the solution increases by 1 unit, then ...”

“...[H₃O⁺] goes down 10-fold and the solution gets more basic, and ...”

“...the ratio of [HA] (“protonated”) to [A⁻] (“deprotonated”) decreases by 10-fold.”

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