Introduction

Formative Assessment Exemplar - CHEM.3.6

Introduction:

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

Of note: All formative assessment clusters were revised based on feedback from educators after being utilized in the classroom. During the revision process, each cluster was specifically checked to make sure the phenomena was authentic to the DCI, supporting information was provided for the phenomena, the SEPs, CCCs, and DCIs were appropriate for the learning progressions, the cluster supported student sensemaking through the Gather, Reason, and Communicate instructional model, and the final communication prompt aligned with the cluster phenomena. As inconsistencies were found, revisions were made to support student sensemaking. If other inconsistencies exist that need to be addressed, please email the current Utah State Science Education Specialists with feedback.

General Format:

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

Accommodation Considerations:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

References:

Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

Teacher Facing Info

Teacher Facing Information

Standard: CHEM.3.6

Assessment Format: Printable or Online Format (Does not require students to have online access) ; Optional video would require online access to watch

Phenomenon	
Students ran an experiment with iodate ion and hydrogen sulfite ion in the presence of starch. They changed the concentrations of the iodate ion and timed how long it took for the blue-black product to appear. They did the experiment again with only one concentration of each ion but changed the temperature and timed how long before the blue-black product appeared. They also added a catalyst at room temperature and timed it.	Proficient Student Explanation of Phenomenon: Several factors affect the rate of reactions. These include an increase/decrease of reaction rate with an increase/decrease of concentration of reactants, changes in temperature, and adding a catalyst. In every factor, either the number of collisions between particles increases and/or the energy is changed for the particles. For concentration, the higher the concentration causes more particle collisions. With temperature increase, the energy increases so more particles have enough energy to react. For a catalyst, the energy needed for the reaction is lower so more particles have enough energy to react.

Cluster Task Statement

(Represents the ultimate way the phenomenon will be explained or the design problem will be addressed)

In the questions that follow, you will analyze patterns in the data to describe the cause and effects of iodine-clock reaction. In addition, you will construct explanations of how temperature, concentration, and the presence of a catalyst affect the rate of the iodine-clock reaction.

Supporting Information

Data was collected and recorded in the supporting information.

IO_3^- + HSO_3^- + starch → product (blue-black color)

To see the reaction, watch the following video: iodine clock reaction.

Table 1: Time to color change when the concentration is varied.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Concentration of	0.005 M	0.010 M	0.015 M	0.020 M	0.025 M	0.030 M

IO_3^-						
Concentration of HSO_3^-	0.05 M	0.05 M	0.05 M	0.05 M	0.05 M	0.05 M
Total time to color change(seconds)	210 s	58 s	49 s	39 s	33 s	27 s

*All trials in table 1 were taken at the same room temperature

Figure 1: Concentration vs. Time for Color Change to Occur from Data Table 1

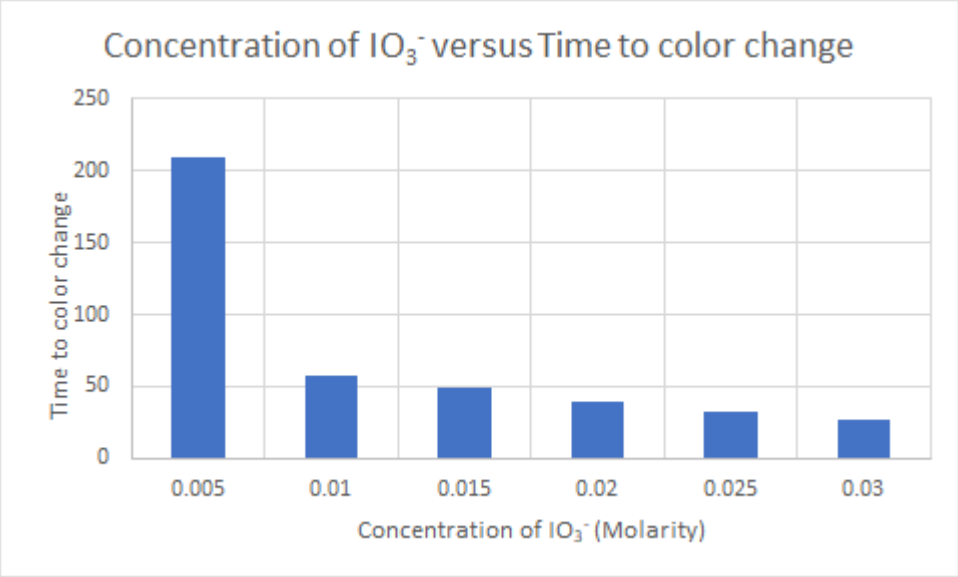
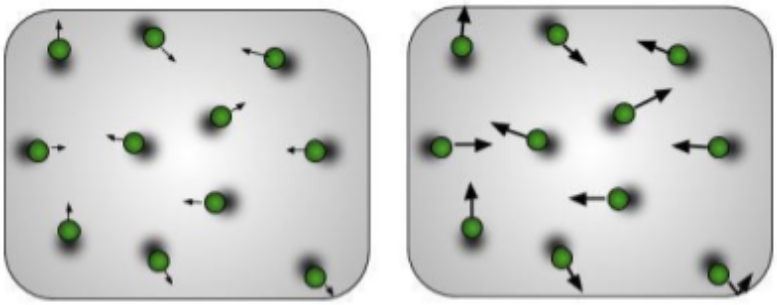


Table 2: Reaction Time Under Different Conditions

	Trial 1	Trial 2	Trial 3
Temperature (°C)	22°C	10°C	60°C
Concentration of IO_3^-	0.03 M	0.03 M	0.03 M
Concentration of HSO_3^-	0.05 M	0.05 M	0.05 M
Total time to color change (Seconds)	27 s	45 s	10 s

Cluster Questions

Cluster Question #___1___ Question Type: SA Practices Sequence: Gather Addresses: ___x_ DCI (PS1.B)	Question 1: Based on the data from **Table 1** and **Figure 1**, circle the words that complete the statement.

__x__ SEP Analyze Data ___x_ CCC Pattern Answer: Decreases, Increases	As the concentration of IO_3^- *<u>increases</u>*, the time to color change *(increases/decreases)* and the rate of the reaction *(increases/decreases)*.
Cluster Question #___2___ Question Type: SA Practices Sequence: Gather Addresses: __x__ DCI (PS1.B) __x__ SEP Analyze Data __x__ CCC Pattern Answer: Increases, Decreases	Question 2: Based on the data from **Table 2**, circle the words that complete the statement. As the temperature of each trial *<u>decreases</u>*, the time to color change *(increases/decreases)* and the rate of the reaction *(increases/decreases)*.
Cluster Question #___3___ Question Type: MC Practices Sequence: Reason Addresses: __x__ DCI (PS1.B) __x__ SEP Constructing explanations __x__ CCC Cause and Effect Answer: A	Question 3: Based on the data from table 1, what statement below best represents what is happening on a molecular level during the chemical reaction in relation to concentration versus reaction rate. a. As concentration increases the reaction rate increases because more molecules are colliding with each other. b. As concentration increases the reaction rate increases because the volume has increased. c. As concentration increases the reaction rate decreases because less molecules are colliding with each other. d. As concentration increases the reaction rate decreases because the volume has decreased.
Cluster Question #___4___ Question Type: MC Practices Sequence: Reason Addresses: __x__ DCI (PS1.B) __x__ SEP Constructing explanations __x__ CCC Cause and Effect Answer: C	Question 4:  Model A Model B A student sketches a model of reacting particles at two different temperatures. The length of the arrow is related to the speed of the particles. The longer the arrow the faster the molecule moves. Which model represents particles at a *<u>lower</u>* temperature? a. Model A because molecules are moving faster and

	therefore have a lower temperature b. Model B because molecules are moving faster and therefore have a lower temperature c. Model A because molecules are moving slower and therefore have a lower temperature d. Model B because molecules are moving slower and therefore have a lower temperature
Cluster Question #___5___ Question Type: MC Practices Sequence: Reason Addresses: __x__ DCI (PS1.B) __x__ SEP Constructing explanations __x__ CCC Cause and Effect Answer: A	Question 5: Which statement below best relates to how temperature affects the rate of reaction? a. As temperature increases, molecules' energy increases leading to a faster reaction rate. b. As temperature increases, molecules' energy increases leading to a slower reaction rate. c. As temperature increases, molecules' energy decreases leading to a slower reaction rate. d. As temperature increases, molecules' energy decreases leading to a faster reaction rate.
Cluster Question #___6___ Question Type: MC Practices Sequence: Reason Addresses: __x__ DCI (PS1.B) __x__ SEP Constructing explanations __x__ CCC Cause and Effect Answer: B	Question 6: A student redoes trial 1 from data table 2 but adds a catalyst. All other factors are the same. A catalyst lowers the energy required for a reaction. Predict what will happen to the time required for the reaction. a. The time is longer because the catalyst removes energy from the reaction. b. The time is shorter because less energy is required for the reaction. c. The time is longer because less energy is required for the reaction. d. The time is shorter because the catalyst removes energy from the reaction.
Communicate: Cluster Question #___7___ Question Type: LA Addresses: __x__ DCI (PS1.B) __x__ SEP Constructing explanations __x__ CCC Cause and Effect Answer:	Question 7: Based on what you have learned, construct an explanation of how temperature, concentration, and the presence of a catalyst affect the iodine clock reaction. Include the following: ● What increasing temperature, increasing concentration, or adding a catalyst does ● A model or description of how the given change affects the motion, collisions, and/or energy of the reactants

Several factors affect the rate of reactions. These include an increase/decrease of reaction rate with an increase/decrease of concentration of reactants, changes in temperature, and adding a catalyst. In every factor, either the number of collisions between particles increases and/or the energy is changed for the particles. For concentration, the higher the concentration causes more particle collisions. With temperature increase, the energy increases so more particles have enough energy to react. For a catalyst, the energy needed for the reaction is lower so more particles have enough energy to react.	

Proficiency Scale

Proficient Student Explanation:

Several factors affect the rate of reactions. These include an increase/decrease of reaction rate with an increase/decrease of concentration of reactants, changes in temperature, and adding a catalyst. In every factor, either the number of collisions between particles increases and/or the energy is changed for the particles. For concentration, the higher the concentration causes more particle collisions. With temperature increase, the energy increases so more particles have enough energy to react. For a catalyst, the energy needed for the reaction is lower so more particles have enough energy to react.

Level 1 - Emerging	Level 2 - Partially Proficient	Level 3 - Proficient	Level 4 - Extending
SEP: Does not meet the minimum standard to receive a 2.	**SEP:** Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. Construct an explanation using models or representations.	**SEP:** Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.	**SEP:** Extends beyond proficient in any way.

	Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events.	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Uses cause and effect relationships to predict phenomena in natural or designed systems. Recognizes phenomena may have more than one cause	**CCC:** Suggests and predicts cause and effect relationships for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Understands that changes in systems may have various causes that may not have equal effects.	**CCC:** Extends beyond proficient in any way.
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	**DCI:** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies.	**DCI:** Extends beyond proficient in any way.

(Student Facing Format on following page)

Student Assessment

Name: _____ Date: _____

Stimulus

Students ran an experiment with iodate ion and hydrogen sulfite ion in the presence of starch. They changed the concentrations of the iodate ion and timed how long it took for the blue-black product to appear. They did the experiment again with only one concentration of each ion but changed the temperature and timed how long before the blue-black product appeared. They also added a catalyst at room temperature and timed it.

Data was collected and recorded in the supporting information.

$$IO_3^- + HSO_3^- + \text{starch} \rightarrow \text{product (blue-black color)}$$

To see the reaction, watch the following video: iodine clock reaction.

Table 1: Time to color change when the concentration is varied.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Concentration of IO_3^-	0.005 M	0.010 M	0.015 M	0.020 M	0.025 M	0.030 M
Concentration of HSO_3^-	0.05 M	0.05 M	0.05 M	0.05 M	0.05 M	0.05 M
Total time to color change(seconds)	210 s	58 s	49 s	39 s	33 s	27 s

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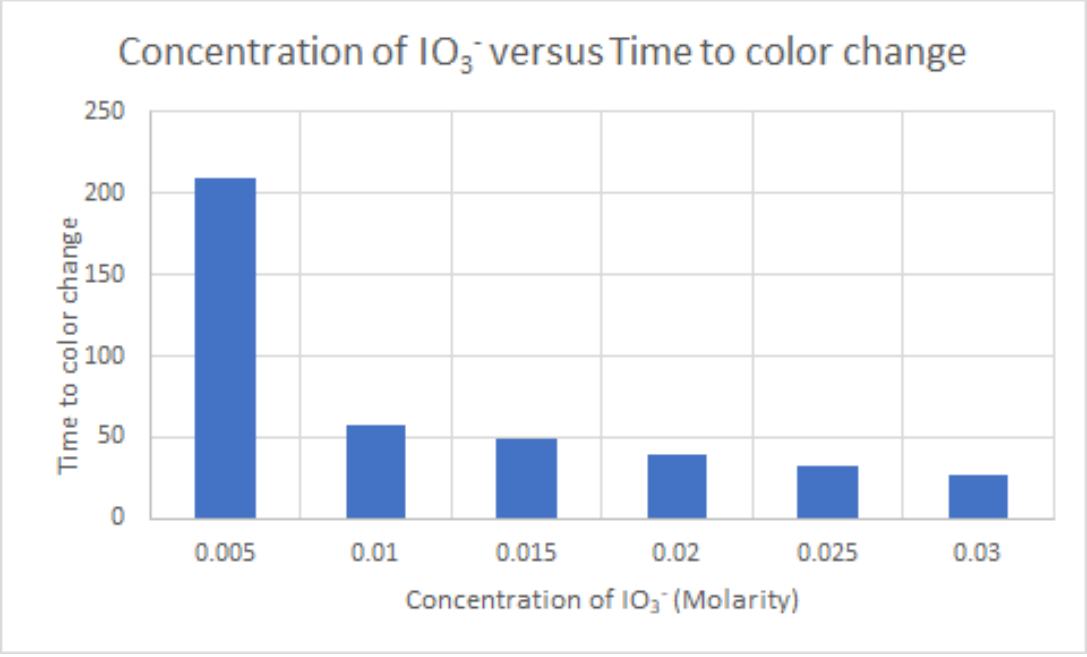


Table 2: Reaction Time Under Different Conditions

	Trial 1	Trial 2	Trial 3
Temperature (°C)	22°C	10°C	60°C
Concentration of IO_3^-	0.03 M	0.03 M	0.03 M
Concentration of HSO_3^-	0.05 M	0.05 M	0.05 M
Total time to color change (Seconds)	27 s	45 s	10 s

Your Task

In the questions that follow, you will analyze patterns in the data to describe the cause and effects of iodine-clock reaction. In addition, you will construct explanations of how temperature, concentration, and the presence of a catalyst affect the rate of the iodine-clock reaction.

Question 1

Based on the data from **Table 1** and **Figure 1**, circle the words that complete the statement.

As the concentration of IO_3^- increases, the time to color change *(increases/decreases)* and the rate of the reaction *(increases/decreases)*.

Question 2

Based on the data from **Table 2**, circle the words that complete the statement.

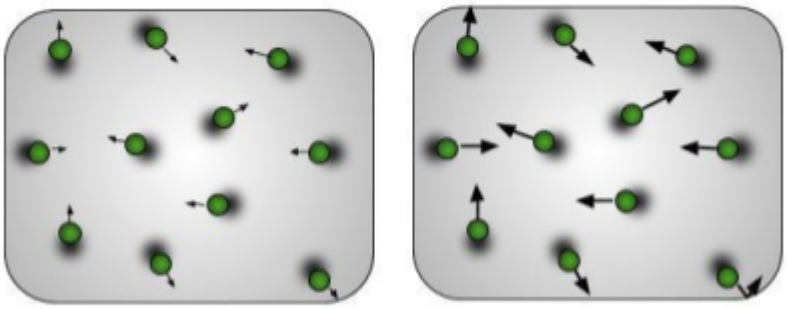
As the temperature of each trial decreases, the time to color change *(increases/decreases)* and the rate of the reaction *(increases/decreases)*.

Question 3

Based on the data from **Table 1**, what statement below best represents what is happening on a molecular level during the chemical reaction in relation to concentration versus reaction rate.

a. As concentration increases the reaction rate increases because more molecules are colliding with each other.
b. As concentration increases the reaction rate increases because the volume has increased.
c. As concentration increases the reaction rate decreases because less molecules are colliding with each other.
d. As concentration increases the reaction rate decreases because the volume has decreased.

Question 4



A student sketches a model of reacting particles at two different temperatures. The length of the arrow is related to the speed of the particles. The longer the arrow the faster the molecule moves. Which model represents particles at a *lower* temperature?

a. Model A because molecules are moving faster and therefore have a lower temperature
b. Model B because molecules are moving faster and therefore have a lower temperature
c. Model A because molecules are moving slower and therefore have a lower temperature
d. Model B because molecules are moving slower and therefore have a lower temperature

Question 5

Which statement below best relates to how temperature affects the rate of reaction?

a. As temperature increases, molecules' energy increases leading to a faster reaction rate.
b. As temperature increases, molecules' energy increases leading to a slower reaction rate.
c. As temperature increases, molecules' energy decreases leading to a slower reaction rate.
d. As temperature increases, molecules' energy decreases leading to a faster reaction rate.

Question 6

A student redoes trial 1 from data table 2 but adds a catalyst. All other factors are the same. A catalyst lowers the energy required for a reaction. Predict what will happen to the time required for the reaction.

a. The time is longer because the catalyst removes energy from the reaction.
b. The time is shorter because less energy is required for the reaction.
c. The time is longer because less energy is required for the reaction.
d. The time is shorter because the catalyst removes energy from the reaction.

Question 7

Based on what you have learned, construct an explanation of how temperature, concentration, and the presence of a catalyst affect the iodine clock reaction. Include the following:

- What increasing temperature, increasing concentration, or adding a catalyst does
- A model or description of how the given change affects the motion, collisions, and/or energy of the reactants