Introduction

Formative Assessment Exemplar - CHEM.4.1

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.

Feedback:

If you have comments or suggestions for this document, please use the Online Feedback Form

References:

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

Utah State Board of Education | Teaching and Learning

Teacher Facing Info

Teacher Facing Information

Standard: CHEM.4.1

Assessment Format: Online Only (Requires students to have online access), Printable or Online Format (Does not require students to have online access)

Phenomenon	
The combustion of natural gas is used to heat many homes.	Proficient Student Explanation of Phenomenon: Natural gas is used to heat homes. This energy comes from rearranging atoms into new molecules, thus giving off energy. For the reaction to occur, energy is added to break existing chemical bonds. When the new bonds form, this energy is released as heat.
Cluster Task Statement	
In the questions that follow, you will develop an explanation for how changes in the bonding of methane (natural gas) releases energy to heat a home.	
Supporting Information	

Figure 1: Gas stoves are used in many homes to cook food.

Image from pixabay.com; CC0

Figure 2: Furnaces in many homes burn natural gas to heat the home.

Image by Dwight Sipler, CC BY https://flic.kr/p/5yi7d4

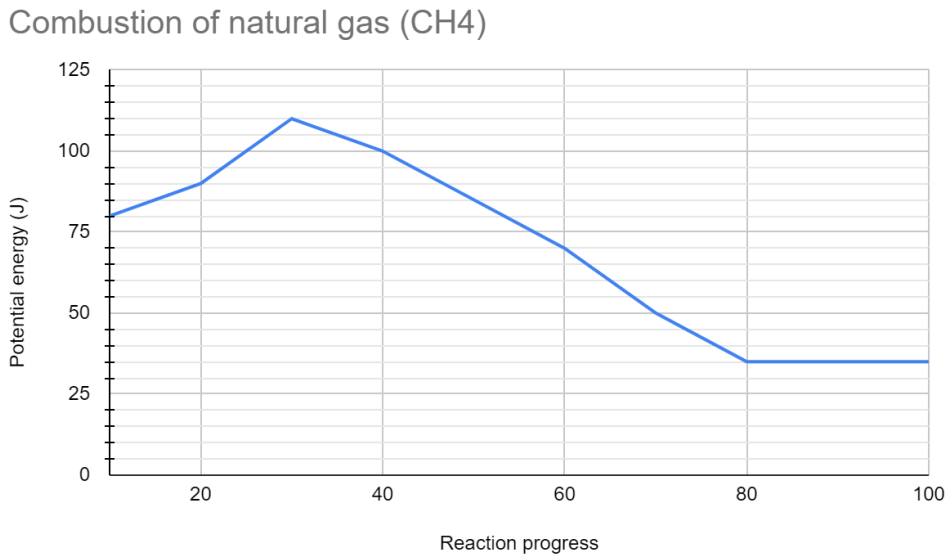
Figure 3: Reaction for the combustion of methane (CH_4) and propane (C_3H_8)

$CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta H = -891$ kJ/mol

$C_3H_8(g) + 5\,O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H = -2219$ kJ/mol

ΔH represents the change in energy of the system.

Figure 4: Energy diagram for combustion of methane.



Cluster Questions	
Gather Cluster Question #1 Question Type: MC Addresses: __x__ DCI: PS1.B, PS3.B _x___ SEP: Construct an argument from evidence __x__ CCC: energy and matter Answer: b	Question 1: Which of the following will release energy? a. When the bonds are broken between the hydrogen atoms and the carbon atom in methane (CH_4). b. When a carbon atom combines with oxygen atoms to form carbon dioxide (CO_2). c. Both of these d. Neither of these
Gather: Cluster Question #2 Question Type: Addresses: __x__ DCI: PS1.B, PS3.B __x__ SEP: Construct an argument from evidence __x__ CCC: energy and matter	Question 2: Use the information in Figure 4 to determine the potential energy during the reaction. At the start of the chemical reaction, the chemicals contain _____ J of potential energy. When the reaction is completed the chemicals contain _____ J of potential energy.

Answer: 80 35	
Reason: Cluster Question #3 Question Type: Addresses: __x__ DCI: PS1.B, PS3.B __x__ SEP: using models, construct an argument from evidence __x__ CCC: energy and matter Answer: b a	Question 3: Complete the sentence by selecting the best option. According to the graph in figure 4, energy is_____ a. entering the system from the surroundings. b. leaving the system to the surroundings. c. neither entering nor leaving. Based on your answer above, the temperature of the surroundings would _____ a. increase. b. decrease. c. remain the same.
Reason: Cluster Question #4 Question Type: multiple choice Addresses: __x__ DCI: PS1.B, PS3.B __x__ SEP: Construct an argument from evidence __x__ CCC: energy and matter Answer: absorbed released	Question 4: Use the information in **Figures 3 and 4** to complete the following. Circle the correct term in the parentheses. Consider the combustion of methane. When the bonds within methane and within oxygen molecules break, energy is (released/absorbed). These atoms then recombine into carbon dioxide and water molecules and energy is (released/absorbed).
Communicate: Cluster Question #5 Question Type: MC Addresses: __x__ DCI: PS1.B, PS3.B __x__ SEP: Construct an argument from evidence __x__ CCC: energy and matter Answer: a	Question 5: How does the amount of energy involved in breaking the bonds compare to the amount of energy involved when forming the new bonds during the combustion of methane? a) Overall more energy is released b) Overall more energy is added c) The amount added and the amount released are the same
Communicate: Cluster Question #6 Question Type: long answer Addresses: __x__ DCI: PS1.B, PS3.B __x__ SEP: Construct an	Question 6: Write a paragraph response to the following prompt using the information provided in Figure 3. Propane is another possible source of fuel for heating and cooking.

argument from evidence __x__ CCC: energy and matter Answer: Propane should release more heat. As shown in figure 3, the ΔH is much more negative, meaning much more heat should be released.	Suppose you have 2 furnaces. The first furnace burns methane. The second furnace burns propane. If equal amounts (moles) of the respective fuels are burned, which furnace would you expect to release more heat? Be sure to support your claim with evidence.

Proficiency Scale

Proficient Student Explanation:
Natural gas is used to heat homes. This energy comes from rearranging the atoms into new molecules, thus extracting energy. For the reaction to occur, energy is added to break existing chemical bonds. When the new bonds form, this energy is released as heat.

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:** Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	**SEP:** Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.	**SEP:** Extends beyond proficient in any way.
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Energy cannot be created or destroyed—only moves between one place and another place, between objects, or between systems.	**CCC:** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	**CCC:** Extends beyond proficient in any way.
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** Energy is released when bonds are formed. Energy is absorbed when bonds are	**DCI:** Any chemical process involves a change in the chemical bonds and the related bond energies. This change is matched by a	**DCI:** Extends beyond proficient in any way.

	broken. Energy is conserved in chemical changes.	difference between the total kinetic energy of the set of reactant molecules before the collision and that of the set of product molecules after the collision (conservation of energy). Some reactions release energy (e.g., burning fuel in the process of oxygen), and others require energy input (e.g., synthesis of sugars from carbon dioxide and water).	

(Student Facing Format on following page)

Student Assessment

Name: _____ Date: _____

Stimulus

The combustion of natural gas is used to heat many homes.

Figure 1: Gas stoves are used in many homes to cook food.

Image from pixabay.com; CC0

Figure 2: Furnaces in many homes burn natural gas to heat the home.

Image by Dwight Sipler, CC BY https://flic.kr/p/5yi7d4

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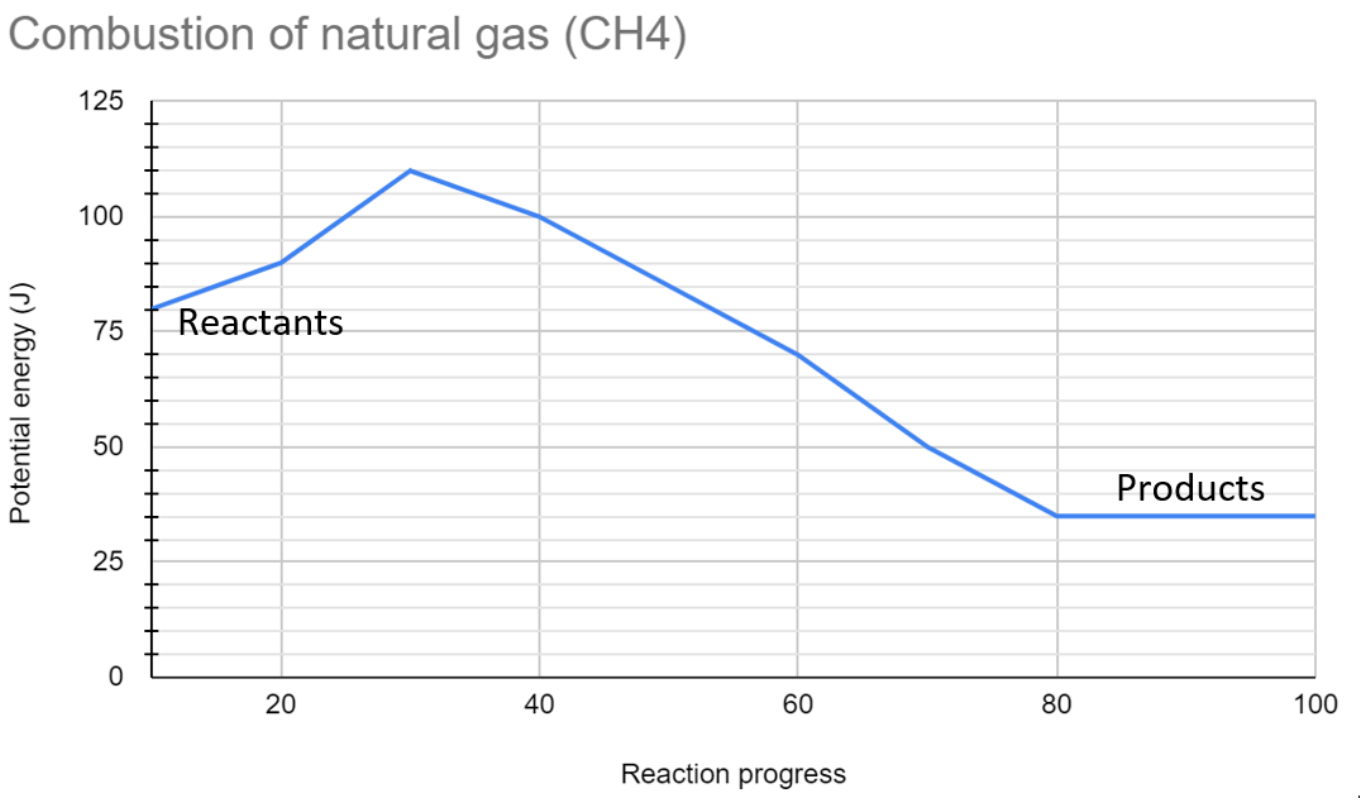
ΔH represents the change in energy of the system.

Figure 4: Energy diagram for combustion of methane



Your Task

In the questions that follow, you will develop an explanation for how changes in the bonding of methane (natural gas) releases energy to heat a home.

Question 1

Which of the following will release energy?

a. When the bonds are broken between the hydrogen atoms and the carbon atom in methane (CH_4).
b. When a carbon atom combines with oxygen atoms to form carbon dioxide (CO_2).
c. Both of these
d. Neither of these

Question 2

Use the information in **Figure 4** to determine the potential energy during the reaction.

At the start of the chemical reaction, the chemicals contain _____ J of potential energy. When the reaction is completed the chemicals contain _____ J of potential energy.

Question 3

Complete the sentence by selecting the best option.

According to the graph of methane combustion in **Figure 4**, energy is_____

a. entering the system from the surroundings.
b. leaving the system to the surroundings.
c. neither entering nor leaving.

Based on your answer above, the temperature of the surroundings would _____

a. increase.
b. decrease.
c. remain the same.

Question 4

Use the information in **Figures 3 and 4** to complete the following. Circle the correct term in the parentheses.

Consider the combustion of methane. When the bonds within methane and within oxygen molecules break, energy is *(released/absorbed)*. These atoms then recombine into carbon dioxide and water molecules and energy is *(released/absorbed)*.

Question 5

How does the amount of energy involved in breaking the bonds compare to the amount of energy involved when forming the new bonds during the combustion of methane?

a) Overall more energy is released
b) Overall more energy is added
c) The amount added and the amount released are the same

Question 6

Write a paragraph response to the following prompt using the information provided in **Figure 3**.

Propane is another possible source of fuel for heating and cooking.

Suppose you have 2 furnaces. The first furnace burns methane. The second furnace burns propane. If equal amounts (moles) of the respective fuels are burned, which furnace would you expect to release more heat? Support your claim with evidence.