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What Difference Does a Catalyst Make?

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POETS NGSS LESSON PLAN 2020 - What Difference Does a Catalyst Make?

Grade: 10-12 Chemistry	**Topic:** Thermodynamics and Kinetics	**Lesson #** 1

Brief Lesson Description:
In this lesson, students will determine whether or not the heat of reaction is affected by the rate of reaction by comparing a decomposition reaction using 2 different catalysts.

Performance Expectations/Standards:
Students who demonstrate understanding can:
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular -level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.A: Structure and Properties of Matter** ● A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **PS1.B: Chemical Reactions** ● 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 in the set of molecules that are matched by changes in kinetic energy.	**Energy and Matter** ● 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.

Specific Learning Outcomes/Including Evidence Statements:

1	Components of the model		
	a	Students use evidence to develop a model in which they identify and describe* the relevant components, including:	
		i.	The chemical reaction, the system, and the surroundings under study;
		ii.	The bonds that are broken during the course of the reaction;
		iii.	The bonds that are formed during the course of the reaction;
		iv.	The energy transfer between the systems and their components or the system and surroundings;
		v.	The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and
		vi.	The relative potential energies of the reactants and the products.
2	Relationships		
	a	In the model, students include and describe* the relationships between components, including:	
		i.	The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.);
		ii.	The energy transfer between system and surroundings by molecular collisions;
		iii.	The total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating the total bond energy changes.); and
		iv.	The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase.
3	Connections		
	a	Students use the developed model to illustrate:	
		i.	The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.)
		ii.	Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings.
		iii.	The energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products.
		iv.	The overall energy of the system and surroundings is unchanged (conserved) during the reaction.
		v.	Energy transfer occurs during molecular collisions.
		vi.	The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy.

Prior Student Knowledge:

1. As the temperature of a substance increases, the collisions of the particles within the substance also increases, therefore increasing the amount of energy within the substance.
2. Potential Energy is stored in the chemical bonds of the substance.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models **Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.** **Develop and use a model based on**	PS3.A: Definitions of Energy Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the	Energy and Matter • Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

evidence to illustrate the relationships between systems or between components of a system.	system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.	

Possible Preconceptions/Misconceptions:

1. The change in heat will vary based on the speed of the reaction (catalyst).
2. The reaction rate of a chemical reaction is constant over time.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
Elephant's Toothpaste for Students:
Let's find out about chemical reactions that produce heat!

Background information for the teacher:

- The chemical formula for hydrogen peroxide is H_2O_2.
- The KI, potassium iodide, and $KMNO_4$, potassium permanganate, serves as a catalyst for the chemical reaction. It speeds up the chemical decomposition reaction of the hydrogen peroxide but remains potassium iodide or potassium permanganate, meaning that it does not chemically change itself.
- The hydrogen peroxide decomposes to form oxygen gas (O_2) and water (H_2O).
- As the hydrogen peroxide decomposes, energy in the form of heat is released causing the bottle to feel warm. This is an example of an exothermic reaction.
- Therefore, the elephant toothpaste is made up of dish soap, water, and oxygen gas.

Materials

- safety equipment (chemical splash goggles, aprons, gloves)
- hydrogen peroxide (13 volume from a beauty supply house)
- liquid dish soap (1 squirt)
- food coloring (optional)
- 5 ml KI or $KMnO_4$
- 20 ml hydrogen peroxide
- 2 - 50 ml test tubes
- test tube rack
- graduated cylinders
- 2 - funnels
- container to "catch" the elephant's toothpaste
- Thermal Camera

Procedure (Be sure to put on goggles and gloves and follow all lab safety rules.) (Aprons will protect clothing.)

1. Measure and add 5 ml of hydrogen peroxide to two separate test tubes.
2. Add a squirt of dish soap to the bottle and gently swirl to mix the soap with the hydrogen peroxide. (Optional: add food coloring and swirl).
3. Place the test tubes into a test tube rack.
4. Place the test tube rack in a container to "catch" the elephant toothpaste.
5. Add 5 ml of KI to one of the test tubes and add 5 ml of $KMnO_4$ to the other test tube.
6. Observe the reaction using a thermal camera.
7. Record your observations.

Student Document

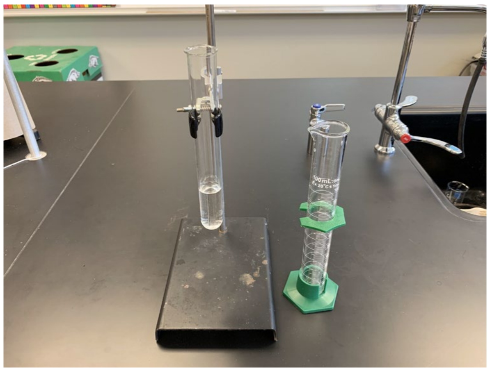
EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Safety: Students must wear goggles, gloves, and closed toed shoes at all times.

Materials:

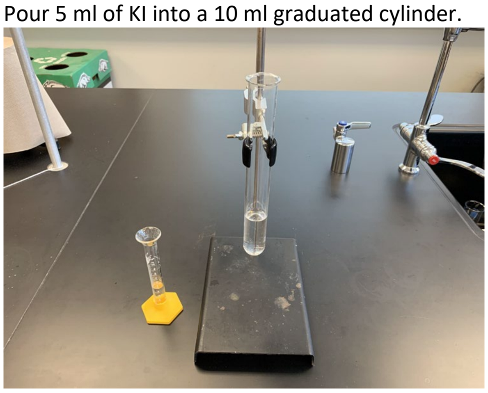
2- 50 ml Test tubes	**0.1** M Potassium Iodide	Balloons	Thermal Camera
Test tube rack	**0.1** M Potassium Permanganate	Funnel	1 - 100 ml graduated cylinder
13 % Hydrogen Peroxide	**Thermometer**	**2** - 10 ml Graduated Cylinders	

Procedures for KI and H_2O_2 :

1. Pour 20 ml of H_2O_2 into a 100 ml graduated cylinder.
2. Pour the 20 ml of H_2O_2 into a 50 ml test tube. Place the test tube in a lab stand as shown.

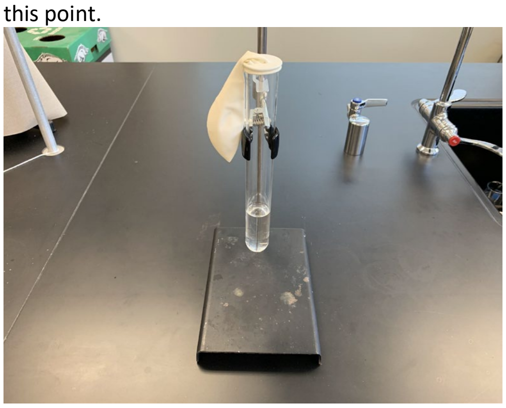


3. Pour 5 ml of KI into a 10 ml graduated cylinder.

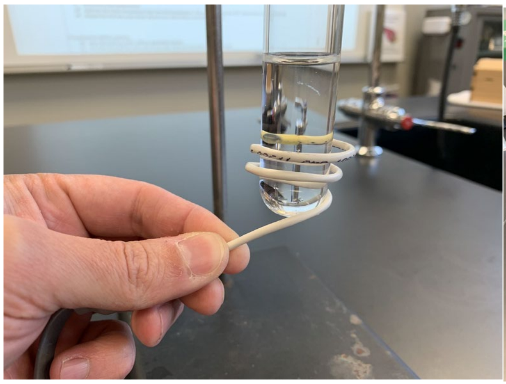
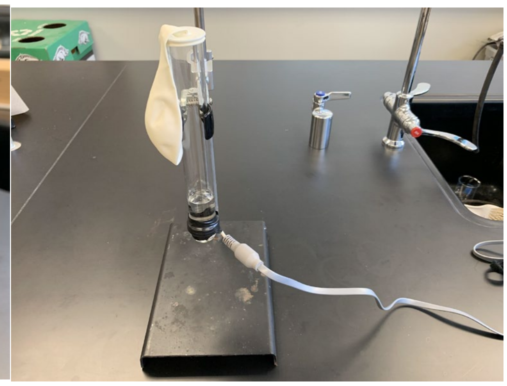


4. Insert the funnel into the mouth of a balloon, and pour the KI from the 10 ml graduated cylinder to the funnel in the mouth of the balloon as shown.

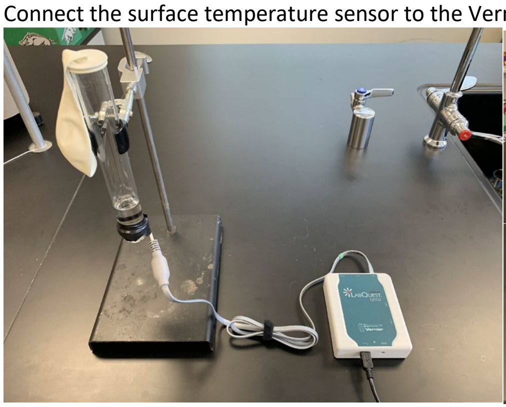
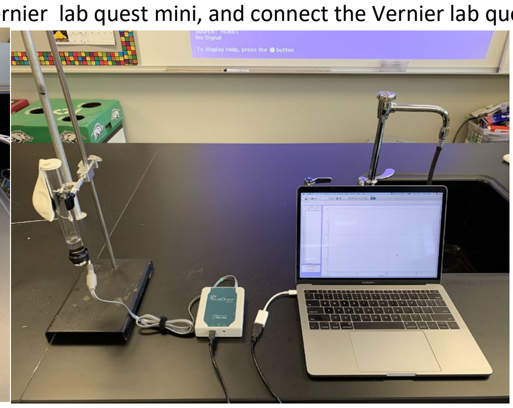
5. Remove the funnel from the balloon.
6. Carefully place the mouth of the balloon over the 50 ml test tube containing the H_2O_2. Be very careful not to mix the KI with the H_2O_2 at this point.



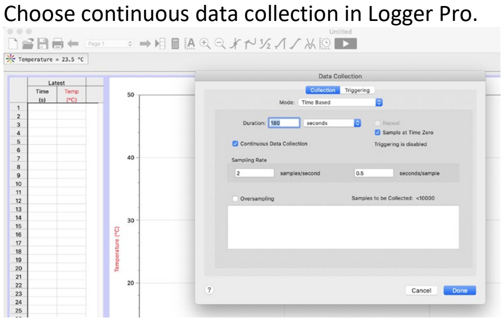
7. Attach the surface temperature sensor to the test tube. Be sure that the sensor is next to the liquid inside the test tube.

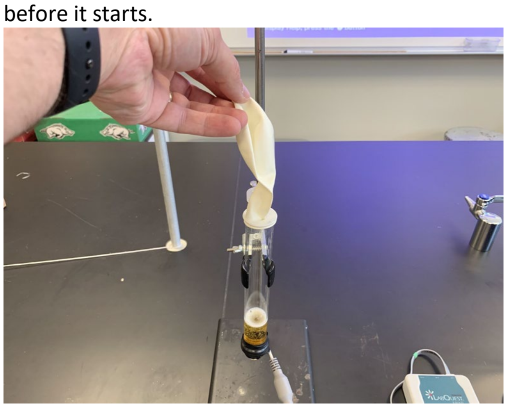
8. Connect the surface temperature sensor to the Vernier lab quest mini, and connect the Vernier lab quest mini to your computer.

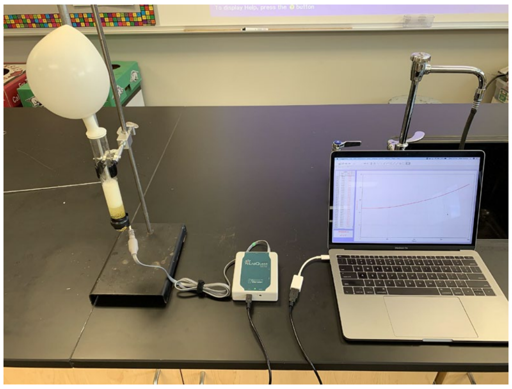
9. Choose continuous data collection in Logger Pro.

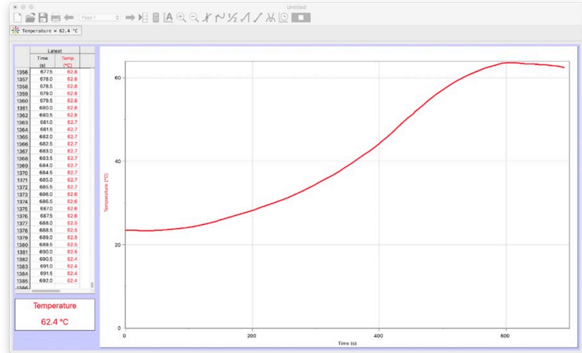


10. Press play to begin the Logger Pro data collection. Give the system a couple of seconds before you begin the reaction.
11. Record the initial temperature.
12. Carefully insert the balloon over the test tube to ensure that the KI is mixing with the H_2O_2. Be patient, the reaction may take some time before it starts.



13. Observe the reaction and record any changes that you may see.
14. Stop the data collection after you notice the temperature decreasing for a couple degrees. You want to make sure that the temperature is in a downward trend before you stop the data collection.





15. Record the final temperature.
16. Subtract the initial temperature from the final temperature. This number will be your ΔT. Record this number.
17. Repeat the trial two more times. Record your observations and data each time.

Procedures for $KMnO_4$ and H_2O_2 :

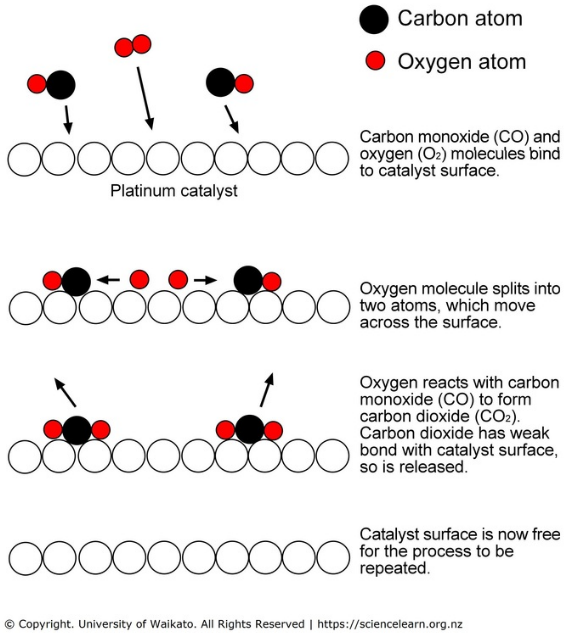
18. Pour 20 ml of H_2O_2 into a 100 ml graduated cylinder.
19. Pour the 20 ml of H_2O_2 into a 50 ml test tube. Place the test tube in a test tube rack.
20. Pour 5 ml of $KMnO_4$ into a 10 ml graduated cylinder.
21. Insert the funnel into the mouth of a balloon.
22. Pour the $KMnO_4$ from the 10 ml graduated cylinder to the funnel in the mouth of the balloon.
23. Remove the funnel from the balloon.
24. Carefully place the mouth of the balloon over the 50 ml test tube containing the H_2O_2. Be very careful not to mix the $KMnO_4$ with the H_2O_2 at this point.
25. Attach the surface temperature sensor to the test tube. Be sure that the sensor is next to the liquid inside the test tube.
26. Connect the surface temperature sensor to the Vernier lab quest mini.
27. Connect the Vernier lab quest mini to your computer.
28. Choose continuous data collection in Logger Pro.
29. Press play to begin the Logger Pro data collection. Give the system a couple of seconds before you begin the reaction.
30. Record the initial temperature.
31. Carefully insert the balloon over the test tube to ensure that the $KMnO_4$ is mixing with the H_2O_2. Be patient, the reaction may take some time before it starts.
32. Observe the reaction and record any changes that you may see.
33. Stop the data collection after you notice the temperature decreasing for a couple degrees. You want to make sure that the temperature is in a downward trend before you stop the data collection.
34. Record the final temperature.
35. Subtract the initial temperature from the final temperature. This number will be your ΔT. Record this number.
36. Repeat the trial two more times. Record your observations and data each time.

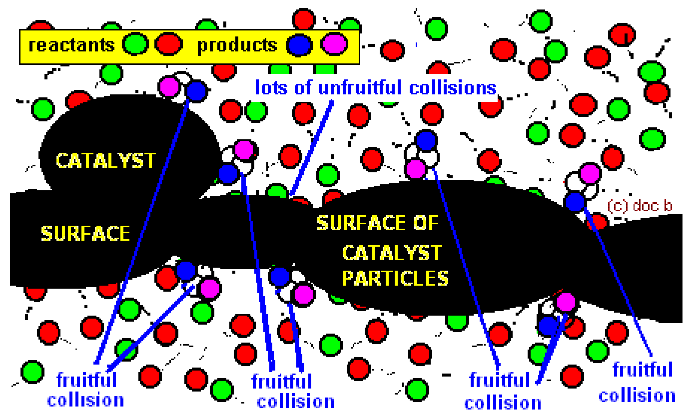
Student Document

EXPLAIN: Concepts Explained:

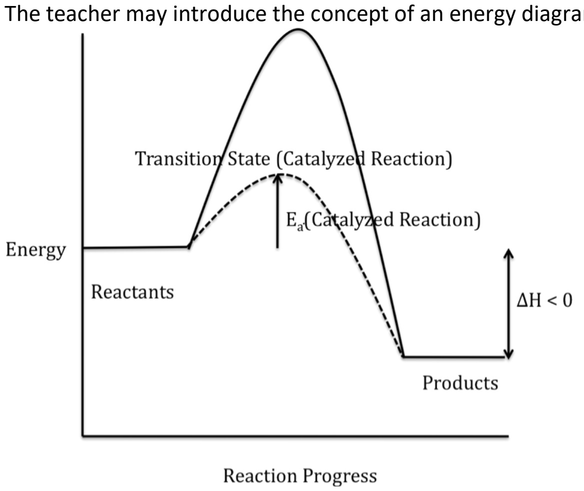
Students should draw a molecular model of how each catalyst affects the decomposition of hydrogen peroxide. Each model should include the energy within the system.

Example of a molecular model:





The teacher may introduce the concept of an energy diagram for this reaction:



As pictured above, the initial and final energies are unaffected by the presence of the catalyst, and only the activation energy is affected.

Vocabulary: Thermodynamics, kinetics, rate of reaction, catalyst, decomposition, exothermic, endothermic, bond energy

Teacher led classroom discourse prompts: (Start with qualitative observations)

1. What quantitative observations did you record for KI?
2. What quantitative observations did you record for $KMnO_4$?
3. Why did this happen?
4. What do you think caused the balloon to expand?
5. Where did the catalyst go?

(Move into quantitative observations)

1. What did you notice in your data collection?
2. Why was there a lag in the rise in temperature in comparison to the start of the reaction?
3. What was the rate of reaction for KI? for $KMnO_4$?
4. Approximate the average temperature change for KI? for $KMnO_4$?

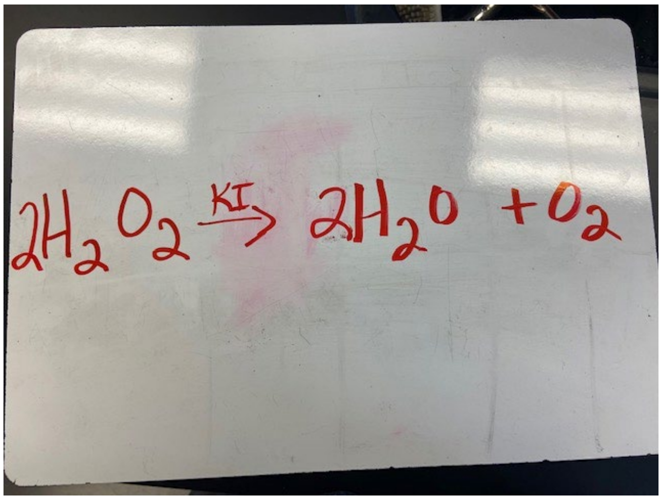
At this point, students should have noticed that the change in temperature was essentially the same for both catalysts. If the students have not arrived at this conclusion, then continue the discussion.

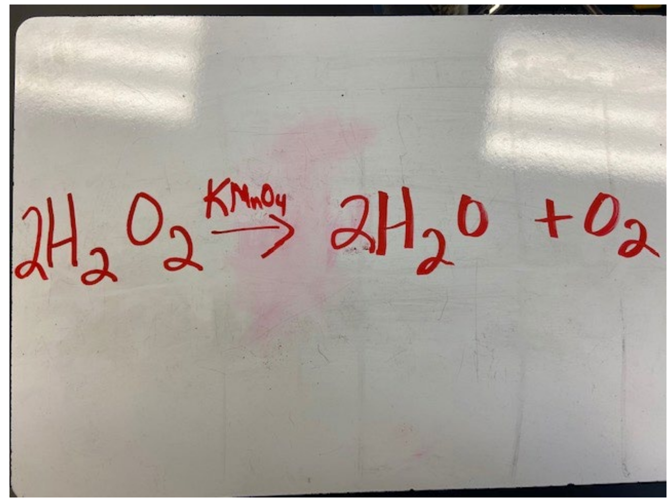
5. Why do you think the changes in temperature were about the same for both catalysts?
6. What is a rate of reaction? What do you know about rates?
7. How did the rates of reaction for each catalyst compare?
8. Does the rate of reaction affect the energy of a reaction?
9. Talk about reactants and products

Students will draw a model to illustrate that the release of energy from a chemical reaction system depends upon the changes in total bond energy.

Students will also produce and analyze graphs showing the energy of 2 different reactions as a model.

Examples of possible student work:





ELABORATE: Application

1) In your group: Based on the data collected for each set of 3 trials, calculate the average temperature change for each catalyst used. Show all calculations. Compare and contrast the 2 average deltas. What conclusions can you make based on this analysis? What questions do you have based on the data?
2) Using the class google sheet, compare your data with the class data
3) Have a class discussion about the spread of data. What might cause your group to have a different average than another group? Introduce variability.
4) Have students calculate Mean Absolute Deviation which is a measure of variability for their own group's data. Talk about the group that has the smallest number for MAD and the group with the largest number. Why are they so different? If given an opportunity to repeat the experiment, do you think you might have less variability? Talk about ways to reduce variability.

NOTE: Mean Absolute Deviation is a 6th grade math standard, nevertheless, students will need to revisit the algorithm. But first discuss ways to represent or find variability. Students might talk about how far each measurement is from what was agreed on as the class average. This is referred to as deviation. Next, talk briefly that direction of the distance away from target number doesn't matter - let students come up with this. This verifies the 'absolute' part of MAD. Mean is the classroom average. That is mean absolute deviation - a numerical value representing variability.

EVALUATE:
Formative Monitoring (Questioning / Discussion): CER Document (See attached)

Guiding Question:

Our Claim:

Our Evidence:	Our Justification of the Evidence:

Summative Assessment (Project Extension):
https://docs.google.com/document/d/1Wh5Cj1j5gqq2fc1t8_Z9Fi4oI1vMTt_bPACCny9DoVQ/edit?usp=sharing

Materials Required for This Lesson/Activity (per class of 20 divided into pairs)			
1	13 % Hydrogen Peroxide(40 Volume) from Beauty Salon 1 Gallon (should be enough for Elephant Toothpaste and 3 trials each of both catalyst)	https://www.amazon.com/Stabilized-Crystal-Liquid-Peroxide-HC-50409/dp/B00TP1IZDE/ref=sr_1_fkmr2_3_a_it?ie=UTF8&qid=1501514177&sr=8-3-fkmr2&keywords=40+volume+hydrogen+peroxide+gallon or	$21

		Beauty Supply House	
1	Package of 72 12" balloons	https://www.walmart.com/ip/Latex-Balloons-Assorted-12in-72ct/32190720	$7
1	.1 Molar Potassium Iodide 500 mils	https://www.flinnsci.com/potassium-iodide-solution-0.1-m-500-ml/p0172/	$11
1	.1 M Potassium Permanganate 500 mils	https://www.flinnsci.com/potassium-permanganate-solution-0.01-m-500-ml/p0176/	$7
	Various other items of lab equipment that most chemistry labs are equipped with		
	Safety Equipment per Student:		
	Goggles Apron Gloves		
7	Temperature Guns and/or Thermal Cameras	(Purchase or possibly utilize a district or regional set)	