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Student Exploration: Collision Theory

Vocabulary: activated complex, catalyst, chemical reaction, concentration, enzyme, half-life, molecule, product, reactant, surface area

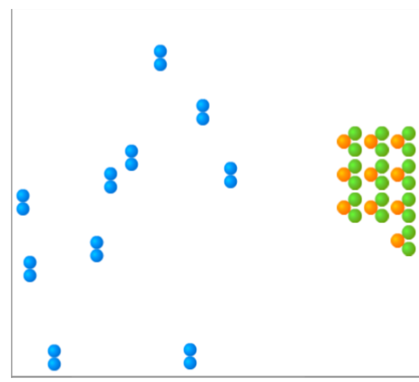
Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Suppose you added a spoonful of sugar to hot water and another to ice-cold water. Which type of water will cause the sugar to dissolve more quickly? The hot water

2. Suppose you held a lighted match to a solid hunk of wood and another match to a pile of wood shavings. Which form of wood will catch fire more easily? The shavings

Gizmo Warm-up

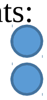
A **chemical reaction** causes the chemical compositions of substances to change. **Reactants** are substances that enter into a reaction, and **products** are substances produced by the reaction. The Collision Theory Gizmo allows you to experiment with several factors that affect the rate at which reactants are transformed into products in a chemical reaction.

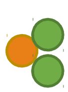


You will need blue, green, and orange markers or colored pencils for the first part of this activity.

1. Look at the key at the bottom of the SIMULATION pane. In the space below, draw the two reactants and two products of this chemical reaction.

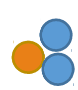
Reactants:

A. 

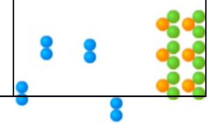
B. 

Products:

A. 

B. 

2. Click **Play** (▶). What do you see? Reactant A bounces around bumping into Reactant B which is on the right side vibrating against the side. When Reactant A succeeds in breaking the bonds of Reactant B the orange substance on Reactant B breaks off and bonds with Reactant A forming Product B, leaving the two green substance molecules which are Product A

Activity A: **Temperature**	Get the Gizmo ready: • Click **Reset** ( ). • Check that the **Reactant concentration** is set to 1.0 mol/L, the **Catalyst concentration** is set to 0.00 mol/L, and the **Surface area** is **Minimum**.	

Question: How does temperature affect the rate of a chemical reaction?

1. Observe: Select the ANIMATION tab. View the animation with **No catalyst** selected.

   What do you see? *I see Reactants A and B meet in the middle, the bonds then break, then bonds form between the two blue atoms and one orange atom, leaving the tw0 green atoms to bond with each other, forming Products A and B.*

   When two reactant **molecules** meet, they form a temporary structure called an **activated complex**. The activated complex breaks up into the product molecules.

2. Observe: Return to the CONTROLS pane. Set the **Temperature** to 0 °C and the **Simulation speed** to its maximum setting. Click **Play**.

   A. Describe the motions of the molecules. *Reactant A molecules are bouncing around with randomly and quickly but some slow down for some reason temporarily and Reactant B is clinging to the side vibrating waiting for Reactant A to bump into it.*

   B. Now set the **Temperature** to 200 °C. How does increasing the temperature affect the motions of the molecules? *Reactant A speeds up, this also speeds the breaking up of the reactant molecules and formation of the product molecules.*

   C. What do you notice about the chemical reaction at the higher temperature? *The higher temperature sped up the reaction time.*

3. Interpret: Select the GRAPH tab. Click the zoom out button (–) until you can see the whole graph. What does this graph show?

Nothing happens for the first 50 to 60 min of the reaction. Then around 60 min mark the concentration of the reactants drops about .1 mol/L and the concentration of the Product rise the same amount. A greater number of bonds broke and a greater number of bonds formed around the 150 min to 160 min mark.

The concentration Of the reactants drop about .6 mol/L. the tapers and holds steady till about 175 min mark then drops an additional .2 mol/L. At each drop in the reactants the concentration of the product rises the same amount.

4. Predict: How do you think temperature will affect the rate of a chemical reaction?

A increase in temperature means an increase in heat energy being applied to the reaction. More energy will speed up the reaction.

(Activity A continued on next page)

Activity A (continued from previous page)

5. Gather data: Click **Reset**. A useful way to compare reaction rates is to record the time required for half of the reactants to react, called the **half-life** of the reaction. With the **Temperature** set to 200 °C, click **Play**. Click **Pause** (⏸) when the number of reactant molecules is 10. Record the half-life time in the first space of the table below.

Trial	200 °C	150 °C	100 °C	50 °C
1	6:04	12:51	20:44	109:32
2	4:49	8:01	14:49	79:56
Mean half-life	5.27	10.26	17.47	94.44

Repeat the experiment at different temperatures to complete the table. (Note: To get exact times, you can refer to the TABLE tab.)

6. Calculate: Calculate the mean half-life for each temperature. Fill in these values above.

(Hint: To get an exact mean, first convert each time to seconds by multiplying the minutes value by 60 and adding this to the seconds. To find the mean in seconds, add up the two times and divide by two. Convert the answer back to minutes and seconds.)

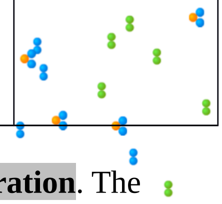
7. Analyze: What do your results indicate? First of all, the speed of the reaction varies at the same temperature. Also, the speed of the reaction slows as the temperature lowers.

8. Draw conclusions: For two molecules to react, they must collide at just the right angle and with enough energy to break the original bonds and form new ones. Based on these facts, why does the reaction tend to go more quickly at higher temperatures?

At higher temps., the molecules have more energy at their disposal to repeatly collide and eventually break their bonds and form new ones

9. Apply: Paper must be heated to 234 °C to begin reacting with oxygen. This can be done by putting the paper over a flame. Why do you think the paper must be heated to start burning?

Because enough energy has to be added to the paper to raise the temp of the paper to the point the paper bonds begin to break causing the paper to change its phase

Activity B: **Surface area and concentration**	Get the Gizmo ready: • Click **Reset**. • Check that the **Catalyst concentration** is set to 0.00 mol/L and the **Surface area** is **Minimum**. • Set the **Temperature** to 200 °C.	

Introduction: Reaction rates are also influenced by **surface area** and **concentration**. The surface area of a solid is a measure of how much of the solid is exposed to other substances. The concentration of a substance is a measure of how many molecules of that substance are present in a given volume.

Question: How do surface area and concentration affect reaction rates?

1. Observe: Change the **Surface area** from **Minimum** to **Maximum**. You can imagine that a solid reactant has been dissolved in a liquid.

   How does this change how many **Reactant B** molecules are exposed to **Reactant A**?

   More of Reactant B is exposed to Reactant A.

2. Predict: How do you think increasing the surface area will affect the rate of the reaction?

   Now that more of Reactant B is exposed, the rate of reaction should speed up.

3. Gather data: Set the **Reactant concentration** to 2.0 mol/L. Use the Gizmo to measure the half-life of the reaction for each surface area setting. (There will now be 20 reactant molecules left at the half-life.) Then, calculate the mean half-life for each setting.

Trial	Minimum surface area	Maximum surface area
1	6:42	1:27
2	4:42	00:34
Mean half-life	5:42	1:00

4. Analyze: What do your results indicate? *An increase in surface area causes the rate of reaction to speed up also because more of the reactants are exposed to one another*

5. Explain: Why does the reaction proceed more quickly when the surface area is increased?

   Because more of the reactants are exposed to each other

(Activity B continued on next page)

Activity B (continued from previous page)

6. Observe: Click **Reset**. Move the **Reactant concentration** slider back and forth. What do you notice? *Lower concentrations regardless of the surface area causes the reaction rater to speed up. The maximum surface area is still significantly faster than the minimum surface area.*

7. Predict: How will increasing the reactant concentration affect the rate of the reaction? Why? *Increasing the reactant concentration will show down the reaction because there are more molecules that need to have bonds broken.*

8. Gather data: Make sure the **Temperature** is 200 °C and the **Surface area** is **Maximum**. Use the Gizmo to measure the half-life for each given reactant concentration. (Note that the number of reactant molecules changes with each concentration.) Calculate the means.

Trial	0.4 mol/L	0.8 mol/L	1.2 mol/L	1.6 mol/L	2.0 mol/L
1	1:52	00:42	1:52	1:02	00:34
2	5:22	2:42	1:32	1:42	00:50
Mean half-life	3.37	1:42	1:42	1:22	00:42

9. Compare: If possible, find the mean times for each concentration for your entire class. What is the mean class time for a concentration of 0.4 mol/L? How about for 2.0 mol/L?

Mean for 0.4 mol/L: *3:37* Mean for 2.0 mol/L: *00:42*

10. Analyze: What do these results indicate? *The lower the concentration the longer the reaction takes.*

11. Apply: Hydrochloric acid reacts with the mineral calcite to produce carbon dioxide gas, water, and calcium chloride. Based on what you have learned in activity A and activity B, what are three things you could do to make the reaction occur more quickly?

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Activity C: Catalysts	Get the Gizmo ready: • Click **Reset** ( ).	

Introduction: A **catalyst** is a substance that helps a chemical reaction to proceed. The catalyst molecules are not changed by the reaction and can be reused over and over again.

Question: How do catalysts affect the rate of a chemical reaction?

1. Observe: Select the ANIMATION tab. Select **With catalyst**, and observe.

   A. What do you see? ____

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   B. Why do you think the shape of a catalyst is important? ____________________

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Many catalysts have a special shape that allows them to bind to specific reactant molecules.

2. Predict: How do you think catalysts will affect the rate of a chemical reaction?

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3. Gather data: On the CONTROLS pane, set the **Reactant concentration** to 2.0 mol/L, the **Surface area** to **Maximum**, and the **Temperature** to 50 °C. Measure the half-life for each given catalyst concentration. Calculate the means.

Trial	**Catalyst concentration**			
	0.00 mol/L	**0.05 mol/L**	**0.10 mol/L**	**0.15 mol/L**

1				
2				
Mean half-life				

4. Analyze: What do your results indicate? _______________

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(Activity C continued on next page)

Activity C (continued from previous page)

5. Explore: Set the **Catalyst concentration** to 0.00 mol/L and the **Temperature** to 0 °C. Click **Play**, wait for 10 minutes of simulated time, and click **Pause**.

   A. What happens? ____

   B. Click **Reset**, set the **Catalyst concentration** to 0.25 mol/L, and click **Play**. After 10 simulated minutes, click **Pause**. What happens now? ____________________________

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   C. Why do you think the catalysts allowed the chemical reaction to take place at 0 °C?

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6. Draw conclusions: What is the usefulness of catalysts? ________________________________

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7. Apply: Most of the chemical reactions inside your body rely on protein catalysts called **enzymes** to take place. For example, the enzyme pepsin helps to break down protein molecules in your stomach. What might happen if your stomach stopped producing pepsin?

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