Red Alert!

MI HSCE

C5.r1a Predict how the rate of a chemical reaction will be influenced by changes in concentration, temperature, and pressure.
C5.r1b Explain how the rate of a reaction will depend on concentration, temperature, pressure, and nature of reactant.
C1.1C Conduct scientific investigations using appropriate tools and techniques.
C1.1E Describe a reason for a given conclusion using evidence from an investigation.
C1.1h Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.
C1.2D Evaluate scientific explanations in a peer review process or discussion format.

NSES

Chemical reactions; interactions of energy and matter

TYPE OF INQUIRY

Guided – Students are open to refine the initial question and design their own experiment, but they are guided in the type of data they will collect.

TIME

Preparation: 15-20 minutes
Prior Knowledge: 10-15 minutes
Prediction: 5-10 minutes
Activity: 45-60 minutes
Results and Discussion: 30-40 minutes

EDUCATIONAL OBJECTIVES

The learner will be able to:

- Identify variables that will change the rate of a chemical reaction.
- Determine how temperature and concentration affect the rate of a chemical reaction.
- Explain, using collision theory, how temperature and concentration affect the rate of a chemical reaction.
- Write a procedure and perform an experiment.
- Collect appropriate data.
- Use data as evidence to support a conclusion.

CONCEPTS ADDRESSED

Chemical reactions
Collision theory
Reaction rates

MISCONCEPTIONS

Students may be under the impression that all chemical reactions occur rapidly because of exciting, instantaneous reactions that teachers often use as demonstrations for their "wow" effect (Brooks, 2006).

This lab will help students to understand that reactions happen over time and different variables influence reaction rates.

PREREQUISITE KNOWLEDGE

Students should understand that particles must collide with sufficient energy and correct orientation for a chemical reaction to occur (collision theory). Students should be able to use a spec-20.

TEACHER BACKGROUND

This lab introduces students to the factors that influence the rate of a chemical reaction: *temperature* and *concentration*. *Surface area* and *pressure* are not addressed, as the reactants in this lab are both liquids, but the same concepts used with concentration can be applied to surface area and pressure when a reactant is a solid or gas, respectively.

Collision theory states that, in order for a chemical reaction to occur, particles of the reactants must come in contact, or collide, with the correct orientation and enough kinetic energy.

Students should discover that increasing the temperature of the reactant(s) speeds up the reaction rate, while decreasing the temperature slows down the reaction rate. Increasing the temperature of the reactants causes the particles to move faster, causing them to collide more often. Colliding more often will increase the number of particles that are in the correct orientation with enough kinetic energy in a given amount of time. Increasing the temperature also increases the kinetic energy that the molecules have when they come in contact, so more particles will have sufficient energy to react.

Students should discover that increasing the concentration of a reactant will also increase the reaction rate, while decreasing the concentration decreases the reaction rate. Increasing the concentration increases the number of particles of a given reactant. This increases the number of collisions between reactants, thus speeding up the reaction rate. Decreasing the concentration decreases the number of particles of a given reactant. This decreases the number of collisions between reactants, thus slowing down the reaction rate.

Increasing concentration has similar effects as increasing surface area in a solid. It increases the number of the particles of a given reactant that are able to collide with other reactant particles.

SAFETY

- Safety glasses must be worn at all times.
- Bleach is harmful to skin, eyes, and if swallowed. Flush skin or eyes with water if they come in contact. If swallowed, seek immediate medical attention.
- Hot plates may become very hot. Have hot pads available for removing glassware from the hot plate.

MATERIALS, PREPARATION, AND DISPOSAL

Make a stock solution of red food coloring diluted to approximately 1 drop/20 mL of water.

Each group will need access to:
A visible spectrophotometer (spec-20)
Approx. 20 mL of diluted red food coloring solution
3-4 plastic pipettes
400 or 500 mL plastic beaker
Thermometer
Stopwatch
8 test tubes
test tube rack
2-3 cuvettes (for spec-20)
4-100 mL beakers
4-200 mL beakers
25 mL graduate cylinder
1 hot plate (group testing increasing temp. only)
A container of ice (group testing decreasing temp. only)

If you do not have a visible spectrophotometer, Vernier probes or colorimeters may also be used.

PRELAB ENGAGEMENT / QUESTIONS

Read the scenarios out loud as a class, and then allow students time to discuss answers in small groups. Discuss answers from groups as a whole class.

You have a big date tonight and you are making dinner for your date. You decide to make steak fajitas, but you are running a little behind schedule. Your date will be here in 5 minutes, you just put 2 steaks on the grill, and you spilled red pop on your white shirt. You want dinner to be ready when he/she arrives and you have to look good.

1. How can you speed up the process of cooking your steaks?
   Turn up the grill
   Cut into strips
   Cover the grill with a lid

You spent hours picking out the perfect outfit, so you don't want to change your shirt. You grab your mom's bleach pen that she keeps in the kitchen, but just put a tiny dot on your shirt.

2. The stain doesn't completely come out, what do you do?
   Add more bleach from the bleach pen
   Students may come up with other answers, but steer them towards the above suggestion

3. Cooking your steaks and removing the stain from your shirt are both examples of chemical reaction. What are some factors that affect the rate of a chemical reaction?
   Turn up the grill/cover with a lid – increase temperature
   Cut into strips - increase surface area
   Add more bleach – increase concentration of a reactant

4. We have discussed collision theory previously, what must happen to particles of reactants in order for a chemical reaction to occur?
   They must collide with the correct orientation and enough kinetic energy.

5. What do you think will happen when you combine red food coloring and bleach?
   Most students will probably know that bleach will "take the color out." All answers are acceptable here.

6. Add 4 mL of the red food coloring solution and 1 mL of bleach to a test tube. Watch the contents of your test tube for 2-3 minutes. Record your observations.
   All students should observe the red color fading and becoming a colorless solution. Some students may notice that this happens over time. They also may notice that it seems to fade quickly at first, and then slows down.

7. If you place a cuvette with red food coloring and bleach in a spectrophotometer, what will happen to the absorbance over time?
   You may have to review the physical meaning of absorbance. Absorbance will be high at first, then decrease as the solution becomes colorless.
   Students may also note that absorbance will depend on the wavelength in which measurements are taken.

8. What will happen to transmittance?
   You may have to review the physical meaning of transmittance. Transmittance will increase as the solution becomes colorless.

PROCEDURE

Before students begin designing their procedure, a class discussion should take place about which variables (from the pre-lab scenario) could be tested using the bleach/red food coloring reaction. Split the variables among groups so that cold, warm, and different concentrations of bleach are all tested by at least one group. All students should test the same control and one other variable.

Students should choose a wavelength close to 525 nm, as this is the wavelength in which the red food coloring absorbs the most light. They will see the greatest change in transmittance in this part of the electromagnetic spectrum. You may want to discuss this

as a class so that all groups are using the same wavelength and results can be compared more easily.

One common problem with these experiments is that students do not begin collecting data as soon as their reaction begins. Bleach can be added quickly by using a pipette and keeping the cuvette in the spec-20 (this method could lead to spills in the spec-20). A plastic pipette can also be used to mix the reactants by squeezing up the bulb a few times before closing the spectrophotometer. Students may also fill one cuvette with bleach and one with food coloring and mix by pouring solution back and forth between cuvettes. It is important for each group, and then the entire class, to discuss which method to use to control this throughout the all experiments.

The teacher should read through each group's procedure before the group begins. Be sure to ask students questions about steps in their procedure that are either unclear or simply don't allow them to collect the appropriate data to answer the research question. You might ask them which independent variable they are testing and what variables they need to think about holding constant.

If students are testing temperature effects, the red food coloring can easily be heated in a hot water bath and cooled in an ice bath. Make sure that students are not heating too much to ensure that the spec-20 is not damaged. A few minutes in a hot water bath will be plenty to see a change in reaction rate. About the same amount of time will be sufficient for the ice bath as well. Students should also be asked if the temperature of their solution will change while it is in the spectrophotometer. Ask students what will happen if efforts are not made to keep the solution warm or cold and how this would affect their results. Students may keep their cuvette in the hot water bath or ice between readings and that they wipe the cuvette before <u>every</u> reading.

DATA (sample student data)

Variable 1: Concentration of bleach

% Transmittance with changing bleach concentrations				
Time (min)	0.5 mL	1 mL	2 mL	3 mL
0.17				
0.33	41.5	71.0	74.5	93.0
0.50	45.5	73.0	79.1	99.5
0.67	47.1	75.0	83.0	100.0
0.83	48.1	78.0	86.5	
1.00	49.5	80.0	90.0	
1.17	50.6	82.5	94.5	
1.33	52.0	84.5	98.0	
1.50	53.0	86.5	100.0	
1.67	54.0	87.5		
1.83	55.0	90.5		
2.00	56.1	93.0		
2.16	57.2	95.0		
2.33	59.0	97.0		

Time (min)	0.5 mL	1 mL	2 mL	3 mL
2.50	60.0	99.0		
2.66	61.2	100.0		
2.83	62.2			
3.00	64.0			
3.16	65.0			
3.33	66.0			
3.50	67.0			
3.66	69.0			
3.83	70.0			
4.00	71.0			
4.16	72.1			
4.33	73.0			
4.50	75.0			
4.66	77.0			
4.83	78.0			
5.00	79.0			

Variable 2: Temperature

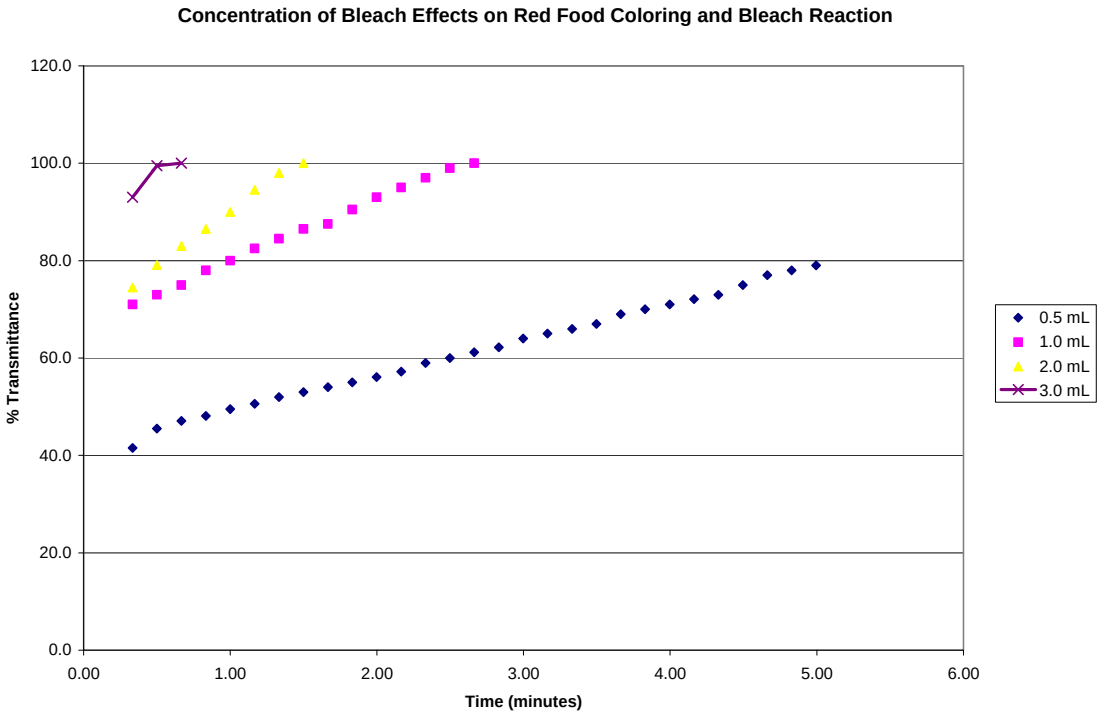
	% T w/ changing temperature	
Time (min)	Room Temp.	60°C
0.00		
0.25	17	25
0.50	19	33
0.75	20	42
1.00	21	50
1.25	23	58
1.50	25	65
1.75	25	71
2.00	26	76
2.25	28	81
2.50	29	84
2.75	30	87
3.00	32	89
3.25	34	91
3.50	35	93

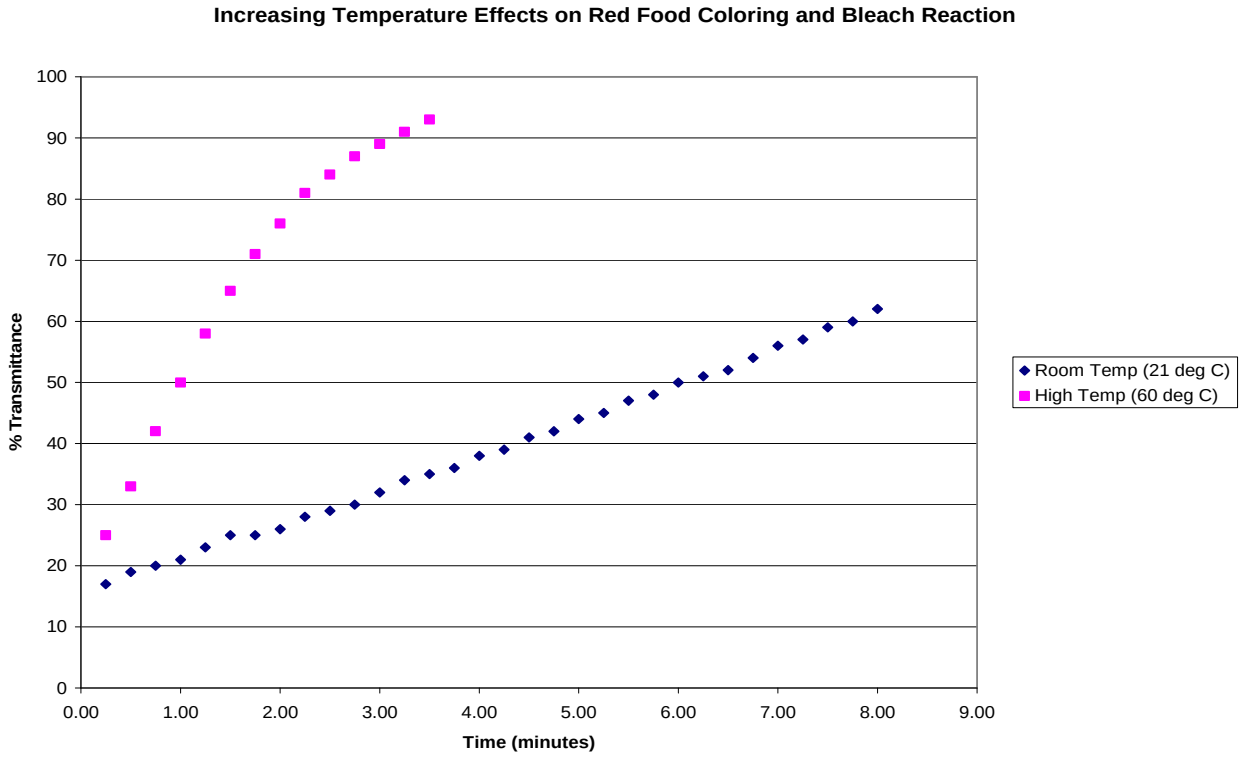
Time (min)	Room Temp.	60°C
3.75	36	
4.00	38	
4.25	39	
4.50	41	
4.75	42	
5.00	44	
5.25	45	
5.50	47	
5.75	48	
6.00	50	
6.25	51	
6.50	52	
6.75	54	
7.00	56	
7.25	57	
7.50	59	
7.75	60	
8.00	62	

RESULTS

As students complete their graphs on their graph paper, hand out overhead transparencies and a different colored marker to each group so they may trace their graph. The instructor can then overlay transparencies on the overhead projector to compare different experiments/treatments. The students can then sketch the results of the other treatments on their own graph. If students use different time intervals, graphs may vary slightly. You may wish to point this out or ask the students if different time intervals will influence the interpretation of the results.

If computers are available to all groups, Excel or another graphing program may be used to generate graphs, such as the ones on the next page.



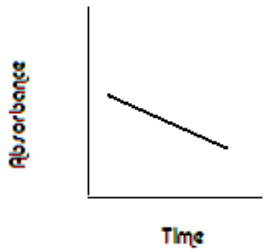


DISCUSSION

1. a. What happens to the red food coloring molecules in your cuvette?
   The red food coloring is converted into a product/different molecule as it reacts with bleach.

   b. What observable property is different about the product?
   It is colorless.

2. a. Sketch what you think a graph of the change in absorbance would look like.

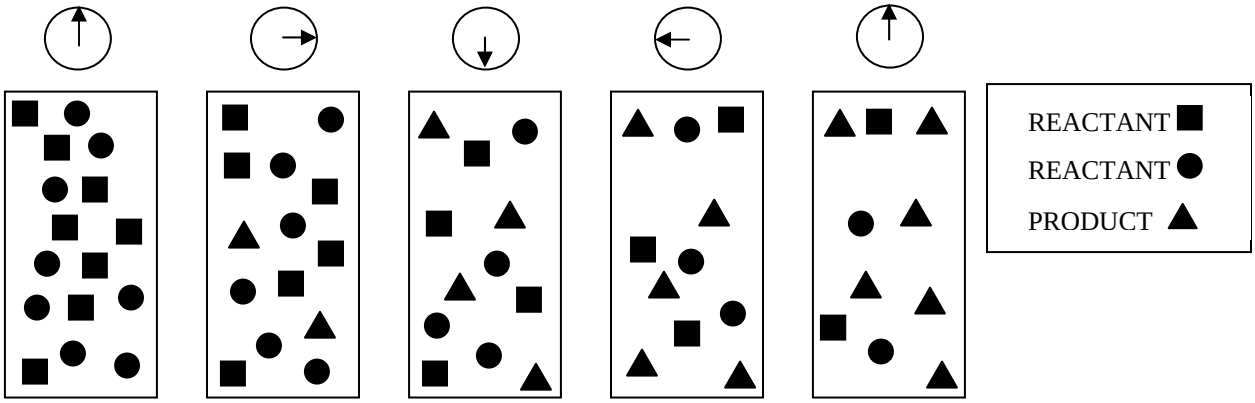


   b. Why does it have this shape?
   Because the amount of light that the solution is absorbing at this wavelength is decreasing as the red color fades. The slope of the graph should be the same as the transmittance, but decreasing instead of increasing.

3. What does the slope of the graph tell you about the reaction?
   The steeper the slope of the graph, the faster the reaction rate.

4. How did each variable affect the reaction rate of the red food coloring/bleach reaction? Use your data as evidence to support your answer.
   a. Temperature
   Heating the reactants increased the reaction rate; the slope of the graph is steeper than the control.
   Cooling the reactants decreased the reaction rate; the slope of the graph is more gradual than the control.
   b. Concentration
   Increasing the concentration of bleach in the reaction increased the reaction rate; the slope of the graph is steeper than the control.
   Decreasing the concentration of bleach in the reaction decreased the reaction rate; the slope of the graph is more gradual than the control.

5. The diagram below describes the rate of your control reaction at the particle level. Draw a similar diagram that shows the variable that you tested and its effect on the reaction rate.
   They should include more particles of one reactant if they increased concentration. If they increased the temperature, they should somehow indicate that particles are moving faster (i.e. motion lines). They should show the difference in reaction rates by an increase in product formation earlier in the series of pictures.



6. Use collision theory to explain why each variable listed below did or did not change the reaction rate between bleach and red food coloring.
   a. Temperature
      Students should explain that when temperature increased, molecules move faster and collide more often and with more energy; or more molecules have adequate KE for effective collisions.
   b. Concentration
      Students should explain that an increase in concentration increases the number of particles, thus increasing the number of collisions in the correct orientation.
7. a. How does the slope of your graph change as the reaction proceeds?
      The slope of the graph becomes more gradual as time passes.
      b. What does this tell you about the reaction rate?
      That the reaction rate is slowing.
   c. Use collision theory to explain why the graph has this shape.
      As more product is formed, there are fewer reactant molecules left to react, so the reaction rate must slow down.
8. Based on your experience in this lab, explain two things you could do to speed up the removal of the Kool-aid stain from your shirt in the pre-lab scenario.
   Students should explain that adding more bleach to the stain should speed up the removal of the stain. Students may also suggest some method of heating up the shirt to increase the reaction rate.

GOING FURTHER

Use your textbook or other sources to answer questions 1-3.

1. What is a catalyst?
   A catalyst is a substance that is not chemically changed during a chemical reaction, but increases the rate of reaction by providing an alternate energy path with a lower activation energy.
2. How does a catalyst affect a reaction rate?
   It increases the reaction rate.
3. Describe, using collision theory, how a catalyst works.
   A catalyst provides a surface in which the reactants may react, helping to orient the reactants correctly when they collide.

The chemical reaction used to produce ammonia is very important in industry. Use the following website to understand how this chemical reaction works and why it is so important (http://www.ausetute.com.au/haberpro.html).

4. You studied and experimented with several factors that affect the rate of chemical reactions in this activity (concentration, temperature, and now catalysts). Which of these are used in the production of ammonia? Explain how they are used.
   The temperature is increased to 400-500°C to increase the kinetic energy of the reactants so they have sufficient energy to react.
   An Iron catalyst is used to enables H_2 and N_2 bonds to be broken easier.
   (It is not necessary for students to have an in-depth understanding of catalysts, but a general understanding of how they work and their importance).
5. Ammonia is used in several different industries. Choose an industry in which ammonia is used and summarize (in 2-3 paragraphs) how ammonia is used and why it is important. You may have to do some additional research.
   Examples of some of the industries that students may choose include:
   Fertilizers
   Explosives
   Plastics
   Pharmaceuticals
   Refrigeration
   Paper

REFERENCES

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